MEDICAL DEPARTMENT
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IN WORLD WAR II

MEDICAL DEPARTMENT, UNITED STATES ARMY

SURGERY IN WORLD WAR II

THORACIC SURGERY

Volume I

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Foreword

With the publication of this volume, the first of two which tell the story of thoracic surgery in World War II, there has been completed one more phase of the historical project in which is being told the total story of the U.S. Army Medical Department in World War II. One of my predecessors, the late Maj. Gen. Merritte W. Ireland, considered the completion of the World War I medical history perhaps the most important achievement of his tour of duty in this office. It gives me great satisfaction that some of the volumes of the far more ambitious World War II medical history are being completed during my own tour of duty.

It is with particular pleasure that I observe the publication of the volumes on thoracic surgery. As commanding officer of the 160th General Hospital in the United Kingdom Base during World War II, I had the responsibility for the thoracic surgery center established there. At this center, rehabilitation of the thoracic casualty, based on British concept, was carried out with an attention to detail not, I believe, achieved at any other installation during the war. At this same center, as is related in detail in the second of the volumes on thoracic surgery, there was also carried out a series of almost fantastically successful operations for the removal of retained foreign bodies from the heart and great vessels.

The story of thoracic surgery in World War II is told so fully in this volume and the volume that follows that little additional comment is needed in this foreword. Three special points, however, might be mentioned.

The first concerns the material collected on 2,267 thoracic casualties by the thoracic surgical teams of the 2d Auxiliary Surgical Group. These data, unique in respect to both number of cases and details concerning them, are evidence of what careful planning and systematic endeavor can accomplish even under the stress of battle. Nothing like them exists in the previous medicomilitary literature. They will serve as a point of departure for all future studies of thoracic wounds.

The second point I would comment on is the system of chest centers, established with the practical purpose of assembling all casualties with the same kinds of injuries under the same roof, so to speak. This system permitted the most efficient use of thoracic surgeons, who were always in short supply, and it resulted in an excellence of care which could not have been achieved had these casualties been scattered through various nonspecialized hospitals under the care of surgeons who, however competent they might be, were, most of them, not thoracic surgeons.

Finally, I would point out that the thoracic surgery volumes, like all volumes in the historical series, are written with candor and frankness. The

primary objective of this entire history is to relate events as they occurred. I believe this objective has been fully achieved. It has certainly been achieved in the thoracic surgery volumes. For example: The results of the management of thoracic wounds in 1944 and 1945 were far better than they had been in any previous war. Frequently they were brilliant. But these good results followed some very poor results in the early months of the war, before policies and practices in this field had become standardized and when surgical procedures were often unnecessarily radical. Those early results, as well as the reasons for them, are described in detail. Such instances of the frank statement of errors could be multiplied. A careful reading of this volume and of the second thoracic surgery volume should mean that such mistakes will not be made again in any future war.

As The Surgeon General, I am responsible for the preparation and publication of the volumes of the historical series. My grateful thanks go to the authors and editors who have worked on them so devotedly and have produced volumes of such outstanding merit.

Particular appreciation is due Dr. Frank B. Berry, Editor for Thoracic Surgery, who came to the rescue of these volumes when the entire thoracic surgery project had bogged down in delays and frustrations. That the task has been carried to a successful conclusion is largely attributable to Dr. Berry's personal enthusiasm, endless patience, and wise guidance.

LEONARD D. HEATON,
Lieutenant General,
The Surgeon General.

Preface

The history of thoracic surgery in World War II comprises two volumes of the total series dealing with the history of the U.S. Army Medical Department in that War. The fact that it did not prove possible to tell the complete story in any briefer compass is, in itself, an indication of the importance attached to this specialty in the Second World War.

The first volume contains a summary of the development of thoracic surgery in previous wars, the general and statistical background of the World War II experience, administrative considerations in the Mediterranean and European theaters and in the Zone of Interior, the evolution of policies of management of chest wounds, and the routine of management of thoracic casualties from their emergency care on the battlefield through their rehabilitation in chest centers.

The second volume is concerned with special types of chest injuries and with the management of general and special complications, with particular emphasis on the wet lung syndrome, hemothorax and hemothoracic empyema, and retained foreign bodies. It also contains a followup study, made in 1960 and 1961, of 167 casualties who sustained chest wounds in the 1943–45 period.

The history of thoracic surgery contained in these two volumes represents the full flowering of this specialty in World War II. Its development, however, was by a process of evolution. In spite of the advances in it between the World Wars, the management of thoracic injuries in the early months of the U.S. participation in the Second World War must be described as tentative. It was based on the previous experience and the personal practices of individual chest surgeons, whose number was small, and of general surgeons, whose experience in this field was limited and sporadic.

By the spring of 1944, a number of developments, including increasing experience with combat-incurred thoracic wounds, permitted the standardization of policies and practices and led to more excellent results than had ever before been achieved in chest trauma. These developments were as follows:

1. It became evident that plasma was not the answer to the problem of resuscitation of combat casualties, including thoracic casualties, and that whole blood was essential to prepare them for, and carry them through, the necessary surgery. In February 1944, a blood bank was established in Naples. Thereafter, blood was available in such amounts as were needed before, during, and after operation, and all the surgeons who handled chest wounds could now administer it according to the necessities of their patients.

2. With the advent of penicillin, the possibilities of thoracic surgery were greatly expanded, and operations previously considered impossible became feasible and safe.

3. Efficient anesthetic apparatus was provided for the use of the anesthesiologists who, by training and experience, were especially qualified to give anesthetics for chest surgery.

4. A routine for the management of chest injuries, with procedures properly spaced as to time and place of performance, was set up in the Mediterranean theater by Col. Edward D. Churchill, MC, Consultant in Surgery to the theater surgeon. It was derived from the wartime experience of the chest surgeons who, in the preceding months, had applied their peacetime training and experience to the management of these injuries, and it was based on the concept that the goal of resuscitation, surgery, and postoperative care was the restoration of normal pulmonary function.

The availability of blood was extremely important. The availability of penicillin was extremely important. Expert anesthesia is always essential for chest surgery. But it was the correct, properly timed and properly spaced surgical management of chest injuries and their sequelae that was primarily responsible for the outstanding results achieved in them in World War II.

The routine of management of chest injuries set up early in 1944 included prompt and adequate debridement; the performance of thoracotomy in forward hospitals only on strict indications; prompt and adequate measures to control such potentially dangerous complications as wet lung; the management of hemothorax by aspiration; the management of organizing hemothorax and hemothoracic empyema by decortication; and the judicious removal of retained foreign bodies, whose presence seldom furnished the sole indication for thoracotomy in a field or evacuation hospital.

As a result of these policies and practices, lives were saved; morbidity was reduced; and most thoracic casualties who survived their wounds were returned to duty or separated from service without the crippling sequelae characteristic of so many thoracic injuries in World War I.

The fact that several circumstances favored thoracic surgeons in World War II does not detract at all from their brilliant achievement. The epidemics of measles and influenza, with their sequelae of pneumonia and empyema, which had plagued the surgeons of World War I did not occur in World War II. In the interim between the wars, the United States had ceased to be a rural nation and had become an urban nation, and most of the World War II troops had long since been exposed to these diseases. Streptococcic infections no longer held the terror they once held because the sulfonamides, which are particularly useful in this type of infection, were already available and had been well tested before the United States entered the war.

The evolution of the management of chest injuries in World War II occurred in the Mediterranean theater, in which fighting began in late 1942. The thoracic surgeons in the European theater built their policies of management largely upon the experience in this theater, but they had ample time to develop their own philosophy before the Normandy invasion.

In May 1943, Maj. Gen. Paul R. Hawley, Chief Surgeon, European theater, visited the Mediterranean theater and observed the management of all varieties

of surgery. Later in the same year, Col. (later Brig. Gen.) Elliott C. Cutler, MC, Senior Consultant in Surgery in the European theater, also visited the Mediterranean theater. By this time, the experience of the first chest center in the theater, at Bizerte, was available for analysis. The thoracic surgeons in the European theater also leaned heavily on the extensive British experience, particularly that of Mr. A. Tudor Edwards, Consultant in Thoracic Surgery to the British Emergency Medical Service. As a result of these various contacts, the policies outlined in the booklet entitled "Manual of Therapy" published in the European theater in May 1944 represented a compendium of previous experiences with thoracic injuries and their management, and they served admirably when they were tested in combat.

The repeated references to the data of the 2d Auxiliary Surgical Group in both these volumes are explained elsewhere, but the explanation might be repeated here. The group material on 2,267 thoracic and thoracoabdominal wounds, like the material on 3,154 abdominal injuries analyzed in another volume of this series, is available for reference because its collection was planned in advance. Thanks to the foresight and insistence of Col. (later Brig. Gen.) James H. Forsee, MC, commanding officer of the group, orders were given to keep detailed records of individual thoracic casualties, and appropriate forms were provided for this purpose. These data could not possibly have been collected after the event. As it is, while some details are understandably lacking, the magnitude of the achievement is impressive. Nowhere else in the medicomilitary literature of World War II or previous wars is there available for analysis and reference such a large series of thoracic and thoracoabdominal injuries.

Similar planning by the consultants in surgery of the Fifth and Seventh U.S. Armies also produced important, though somewhat less extensive, data.

The development of specialty centers was one of the important medical advances in World War II. Some of these centers existed in World War I, but thoracic surgery had not yet reached sufficient stature to be included among them. Specialty centers were established early in the Second World War, and thoracic surgery centers were among the earliest to be set up, in the Mediterranean and European theaters as well as in the Zone of Interior. The concentration of thoracic casualties in these centers permitted the most effective use of the always limited number of thoracic surgeons; greatly extended the experience of these surgeons, and thus resulted in constantly improving care of patients with these injuries.

The emphasis put upon rehabilitation in World War II was a continuation of the similar, but less intensive, efforts in the same direction in World War I. In World War II, this phase of the management of chest injuries probably developed most intensively in the European theater, where circumstances were highly favorable for the establishment of chest centers and where the influence of the British emphasis upon rehabilitation was most apparent. In one form or another, however, rehabilitation of chest casualties was uniformly practiced.

It is one of the reasons why so many thoracic casualties could be returned to duty and why Veterans' Administration hospitals are not caring for the army of chest cripples who required multiple operations and years of hospitalization after World War I.

Theater consultants in thoracic surgery were not appointed in World War II, but the consultants in surgery in both the Mediterranean and the European theaters had a special interest in this field and exercised wise and helpful guidance in it. Their efforts were supported, in turn, by the theater surgeons: Brig. Gen. Frederick A. Blessé and Maj. Gen. Morrison C. Stayer in the Mediterranean theater and General Hawley in the European theater. The theater surgeons encouraged meetings of consultants, at which it was possible to exchange ideas and after which information could be promptly disseminated.

Immediately after the war in Europe ended, the Consultant in Surgery, Seventh U.S. Army, was ordered back to Naples, to consolidate the experiences of the Seventh U.S. Army with that of the Fifth U.S. Army and thus provide a broader perspective derived from the dual experience.

A special word should be said about the excellent liaison which existed between thoracic and other surgeons also in the U.S. Army and their counterparts in the Allied armies. The consultants' meetings in the European theater always included British surgeons, both in the United Kingdom Base and on the Continent, where there were cordial relations with the surgeons of the British 21 Army Group. In the Mediterranean theater, contacts with British surgeons were chiefly local but no less cordial. At the larger medical meetings of U.S. Army surgeons, such as those held in Naples, British surgeons from nearby hospitals were always in attendance.

Early in 1943, the theater consultant in surgery had frequent contacts with the thoracic surgeons in the group of British hospitals near Algiers. Colonel Churchill visited one of these hospitals and observed the work with penicillin done by Dr. (later Sir) Howard Florey and his team. The chief of the surgical service, 9th Evacuation Hospital (later Consultant in Surgery, Seventh U.S. Army), also observed the work with penicillin and later visited several British hospitals, including a field hospital, two casualty clearing stations, and a general hospital. Throughout the war, Colonel Churchill kept in close touch with the British surgical consultants in the Mediterranean theater, Brigadier J. M. Weddell, RAMC, and Brigadier Harold Edwards, RAMC. The policies in chest surgery established in this theater were influenced by the information he received by personal contacts with Sir W. Heneage Ogilvie, from his earlier British experience in the Middle East. Colonel Churchill also had early and frequent contacts with Col. A. L. d'Abreu, RAMC.

Early in the war, Colonel Churchill had the good fortune to know Col. Etienne Curtillet, Professor of Surgery, University of Algiers and Chief Surgical Consultant, French 1st Army. During the planning for the invasion of southern France by the Seventh U.S. Army, the consultant in surgery to that Army had many and useful contacts with Colonel Curtillet, which continued throughout the entire campaign.

The story told in these two volumes is thus based upon a broad and varied experience with thoracic injuries in World War II, during which the achievements in this field laid the foundations for the brilliant advances in it which have occurred since the war. The emphasis in this history, it should be noted, is factual. The aim has been to relate the events in chronicle form, with no attempt at a critique of the motives behind, or the reasons for, the various actions taken.

The story of thoracic surgery in these two volumes covers only the Mediterranean and European theaters and the Zone of Interior. For a number of reasons, chest surgery in the Asiatic-Pacific theater will be discussed in the volume dealing with surgery in those areas.

The type of warfare in this theater was very different. This war was fought in scattered areas; on numerous, often widely separated islands; in jungles; in a tropical climate that was humid as well as hot and in which rainfall was frequent and torrential; in an environment in which parasitic and other tropical diseases furnished problems that were often more serious than the problems of battle injuries; and in areas in which transportation and evacuation were always slow and difficult.

It is small wonder that in the Asiatic-Pacific theater, infected hemothorax, empyema, and other complications of chest injuries were more frequent than in other theaters. It is a tribute to the skill and devotion of the surgeons who worked in these areas that their incidence was not higher.

It would be impossible to produce books of the range of these volumes on thoracic surgery without the painstaking and devoted assistance of a great many persons and agencies. In the end, for a variety of reasons, the chief responsibility for the preparation of this material fell upon a relatively small number of authors. It is a pleasure to make acknowledgment to them:

Dr. Brian Blades (formerly Col., MC), Consultant in Thoracic Surgery to The Surgeon General and chief of the Thoracic Surgery Section at Walter Reed General Hospital, Washington, D.C., during World War II.

Dr. Lyman A. Brewer III (formerly Maj., MC), who served with Thoracic Surgical Team No. 2, 2d Auxiliary Surgical Group, in the Mediterranean theater and later in the European theater.

Dr. Thomas H. Burford (formerly Maj., MC), who served with Thoracic Surgical Team No. 3, 2d Auxiliary Surgical Group, in the Mediterranean theater.

Dr. B. Noland Carter (formerly Col., MC), Assistant Director, Surgical Consultants Division, Office of The Surgeon General. Dr. Carter, in addition to preparing the chapters which carry his name, reviewed the entire manuscript and made helpful suggestions.

Dr. Michael E. DeBakey (formerly Col., MC), Chief, Surgery Branch, Surgical Consultants Division, Office of The Surgeon General, and now chairman of the Advisory Editorial Board for Surgery.

Dr. Dwight E. Harken (formerly Lt. Col., MC), Regional Consultant in Thoracic Surgery to the Senior Consultant in Surgery, European theater. Dr. Harken also directed the chest center at the 160th General Hospital.

Mr. Milton C. Rossoff, Assistant Chief, Statistical Analysis Branch, Medical Statistics Division, Office of The Surgeon General, collected and tabulated the official statistics for the thoracic surgery volumes.

Mr. Melvin J. Hadden was responsible for the artwork in both volumes. He made usable many illustrations which originally seemed beyond salvage.

Grateful acknowledgment is also due to a number of the personnel of The Historical Unit, U.S. Army Medical Service:

Maj. Albert C. Riggs, Jr., MSC, Chief, General Reference and Research Branch, and Mrs. Esther E. Rohlader, Assistant Chief, provided much of the basic data for these volumes and patiently and efficiently answered endless queries and tracked down numerous obscurities to their final solution.

Mrs. Pauline B. Vivette, Assistant Chief, Editorial Branch, prepared both volumes for publication.

Mrs. Hazel G. Hine, Chief, Administrative Branch, handled the multiple details connected with the preparation of volumes issued under Government auspices and also supervised the final typing of the manuscript.

Finally, a special word of appreciation is due to two other persons who worked on these volumes:

Miss Elizabeth M. McFetridge, Associate Editor for the surgical series of volumes, who, after many discouragements, was able to bring together the material prepared by the group of thoracic surgeons who worked in the Mediterranean and European theaters and to prepare it for publication.

Col. John Boyd Coates, Jr., MC, who has been assigned by The Surgeon General as Director, The Historical Unit, U.S. Army Medical Service, and Editor in Chief of the history of the U.S. Army Medical Department in World War II. Colonel Coates, who served in World War II as Executive Officer, Medical Division, Third U.S. Army, saw the unfolding of the story of thoracic surgery in the European theater and, during the campaign, was in frequent contact with the Consulting Surgeon, Sixth U.S. Army Group. His firsthand knowledge has been useful, and his cooperation in all the work on these two volumes has been most helpful.

FRANK B. BERRY, M.D.

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CHAPTER I

Historical Note

Frank B. Berry, M.D.

EARLY OBSERVATIONS

Military surgery is as old as man himself, and battle wounds of the chest, and fatalities from them, are as old as military surgery. Homer described thoracic wounds vividly and with anatomic correctness. He also described how arrows rebounded harmlessly from the plated steel breastplates worn by soldiers during the Trojan War (*1*). It was not until World War II that U.S. Army Air Force crews began to have a comparable form of protection with the provision of flak suits. Later, in the Korean War, ground troops were provided with plastic body armor.

Hand-to-hand fighting determined the character of all wounds for another 2,500 years. Gunpowder was invented early in the 13th century, but cannon and gunshot were not employed effectively in the West until the Battle of Agincourt in 1415. Hieronymus Brunschwig (*2*) of Strasbourg, in 1497, was apparently the first surgeon to describe "Wound :s shot with a gonne." Like other surgeons of his time, he believed that the damage was caused by "the venym of the powder." This concept was dispelled by Paré some 40 years later.

Theodoric (*3*) was probably the first to describe the principles of debridement, in the latter half of the 13th century. He used the Latin word "abradantur" (abradere, to scrape off, to shave) and emphasized that the edges of the wound should be thoroughly trimmed, that all fuzz and hair should be removed, and that above all the wound must be thoroughly cleaned. Debridement was described with clarity and vision by Thomas Gale in 1586, and it is ironic that its principles and technique had to be learned over again in World War II, more than three and a half centuries later.

Up to this time, no special attention had been paid to wounds of the chest, nor was any special attention paid to them in the next two centuries. John Hunter, who served as an Army surgeon in 1761, remarked that while little had been done for them, something probably could be accomplished for the good of the patient. His only contribution, however, was the tentative suggestion that hemothorax might be treated by allowing the fluid to run out of the wound.

Baron Dominique Larrey, during the Napoleonic Wars, devised the system of battlefield evacuation and triage—another lesson finally learned in full in World War II—and also made certain recommendations for the management of chest wounds. Because he had observed that results were poor in penetrating wounds in which the traumatic thoracic opening was larger than the glottis, he

recommended, as had John Hunter, that the casualty be placed on the wounded side, to permit the blood to drain out of the chest cavity, and that the chest then be closed. He described several patients in whom dramatic improvement had occurred and recovery had followed when this plan was used. Closure of chest wounds had been mentioned by John de Vigo early in the 16th century, and Paré said that the practice was founded on reason and truth, though he recommended that the closure should not be effected for from 48 to 72 hours after the injury, to prevent an accumulation of blood. Larrey's bold translation of advice into practice represented the first really notable advance in the management of these wounds.

THE CRIMEAN WAR

Fraser (*4*), in the review of the literature reported in his small monograph on wounds of the chest in the Crimean War, found little information on these wounds as compared with wounds of the extremities and joints, which required "showy manual ability." The single treatise entirely devoted to penetrating wounds was by Mayer of St. Petersburg, and there were only 33 reports of such wounds in five British medical journals between 1825 and 1853. Fraser also commented on the small number of preparations of lung wounds in British hospital museums; there were only seven at the Royal College of Surgeons, three at St. Thomas' Hospital, two at St. George's Hospital, and one at University College. At Chatham there were none.

Fraser's monograph contains chapters on diagnosis, prognosis, and complications of wounds of the chest; wounds of the diaphragm with herniation are discussed under complications. The Crimean experience made the author doubt that many of the cases reported in the literature as recoveries were really wounds of the lung. He regarded most of them, like most of the cases reported from Guy's Hospital (table 1), as wounds in which the lungs had escaped damage and only the pleura was involved. He shared the general opinion of others who wrote on the subject that most deep wounds of the lung were fatal.

"Paracentesis thoracis" was recommended for injuries in which blood or serum accumulated without a free mode of exit and in which movement of the lung was impeded. It was recommended that it be performed without delay.

Fraser considered that there might be more danger in attempting to remove a foreign body than in permitting it to remain in situ, "seeing the lengthened periods during which bullets may remain innocuous in the human body," because in the attempt at removal a relatively minor wound might be converted into a penetrating wound. He granted that there were cases in which the presence of the foreign body might be productive of "serious mischief and danger," and he also advised the removal of some objects if "for no other motive than great peace of mind which this event invariably induced in the patient."

Venesection was routine at this time, but Fraser termed it "this murderous act." He described a patient who recovered, after being bled 100 ounces in a month, "at the expense of an empyema and thanks to an iron frame."

TABLE 1.—*Number of chest wounds on the occasions named, and from the authorities quoted, with the percentage of deaths to wounded, 1859*

Action or authority	Wounded	Deaths	
	Number	*Number*	*Percent*
The Director-General's records prior to Crimean War	39	27	70. 0
Crimea	474	135	28. 5
Simpheropol (Russians)	200	197	98. 05
Toulouse	106	50	50. 0
Quebec	26	2	7. 07
Carlist War	29	27	100. 0
Paris, 1830	[1] 20	10	50. 0
Paris, 1848	9	4	44. 0
Paris, 1850	11	5	45. 5
Battle of Kilet	21	11	50. 0
Battle of Idstead	97	17	17. 0
Battle of Canton	4	4	100. 0
M. Meniere	20	20	100. 0
M. Legonest	6	3	50. 0
Guy's Hospital Reports	[2] 72	9	12. 5
Danish War (Report of Chief Surgeon Schytz. Total wounded, 227)	10	2	20. 0
Dr. Kidd	36	24	66. 0
Total	1, 180	547	

[1] De Lambale and Baudeus.
[2] Of this number, the lung was really wounded in two cases only.
Source: Fraser, Patrick: A Treatise Upon Penetrating Wounds of the Chest. London: John Churchill, 1859.

According to Fraser, 474 of the 12,094 wounds recorded in the Crimean War (3.9 percent) involved the chest, and 135 of these (28.5 percent) were fatal (table 1). Included in the chest wounds were 164 of the lung (1.35 percent of the total number of wounds), of which 130 (79.26 percent) were fatal. The case fatality rate for wounds of the lung in the French Army was reported as 91.6 percent.

THE CIVIL WAR

Of a total of 253,142 wounds recorded in the Civil War, 20,607 (8.1 percent) involved the chest, and 8,715 of these (42.3 percent) were penetrating wounds (*5*). The overall case fatality rate for chest wounds was 27.8 percent and for penetrating chest wounds 62.6 percent. A number of cases were reported in which complete recovery followed gunshot wounds of both lungs. A number of recoveries were also reported after penetrating gunshot fractures of the sternum, apparently because the causative missiles were of low velocity.

In 1863, Assistant Surgeon Benjamin Howard recommended to Brig. Gen. William A. Hammond, The Surgeon General, that penetrating wounds of the chest in which suppuration had not occurred should be managed by removal of all foreign bodies; control of bleeding; paring of the edges of the wound; closure by metallic sutures; and the application of an airtight dressing, so

that the wound would be hermetically sealed. In this recommendation, the implications of the physiology of chest wounds, their mechanics, and the principles of wound suppuration and wound healing were all overlooked. Because of failure to realize that sealing the wound hermetically was only part of the problem, infection was common, and a high case fatality rate was inevitably associated with this type of treatment.

Pneumothorax is mentioned in the Civil War history a number of times but apparently seldom reached an alarming stage. Tension pneumothorax is mentioned only a half dozen times.

Hemothorax, either alone or in combination with pneumothorax, was recognized as a dangerous complication, particularly because of the extreme dyspnea often associated with it. Early in the war, it was believed that the surest way to arrest bleeding was by bleeding the casualty further. In the Confederate Manual used during the war, however, venesection was described as a time-honored absurdity, and it is doubtful that it was ever practiced by any Confederate surgeon. The routine plan, when hemothorax was present, was to try to identify the bleeding point, control it, and then employ such general measures as cold acidulated drinks together with the administration of digitalis or opium. It was recognized that if the hemothorax was not absorbed, empyema would result.

Thoracentesis was used to relieve the effects of effusions resulting from acute and chronic pleurisy or from "traumatic pneumonia" (a term used to indicate infected hematoma, atelectasis, lung abscess, and other infectious sequelae). This method was not used, as in World War II, to evacuate hemothoraces and promote rapid expansion of the lung.

Operation was sometimes necessary to control bleeding from the great vessels. The usual procedure was to ligate only the proximal end of the vessel, and it is not surprising that there were no recoveries in wounds of the axillary artery, though there were 5 survivals in 25 casualties with wounds of the subclavian artery.

Four recoveries were recorded in gunshot wounds of the heart. Patients with wounds of the pericardium sometimes languished for several weeks with suppurative processes, but, in one series of 51 cases, there were 22 recoveries. It was noted that extreme dyspnea might accompany a wound of the heart because of intrapericardial pressure, which could be relieved by paracentesis.

Wounds of the esophagus are not specifically mentioned in the Civil War history, but a disproportionate amount of space is given to descriptions of hernia of the lung. Such hernias, it was stated, were extremely uncommon among British casualties at Waterloo as well as in the Crimean War. One case, described in detail, was managed by the technique first described by Tolandus of Parma in 1449 (*1*) and used successfully by Whittemore (*6*) in 1929 on nine patients. This technique, which amounts to a two-stage lobectomy, consists of creation of a hernia of the lung, followed by excision of the protrusion after adhesions have formed.

WORLD WAR I

General Considerations

It is difficult for a modern surgeon to visualize the status of surgery at the end of the Civil War. Techniques of anesthesia were limited. Antisepsis and asepsis were still undreamed of. Medical schools were poorly organized and administered. Programs of interne and residency training did not exist. Channels for dissemination of medical information were few. Within the Army Medical Department, both order and system were lacking.

It is not surprising, therefore, that in the Franco-Prussian War, which broke out in 1870, 5 years after the end of the Civil War, few advances were made in the management of wounds. When World War I broke out in 1914, enormous strides had been made in medicine and surgery, based on Pasteur's work in bacteriology and Lister's work on antisepsis, out of which the modern concept of aseptic surgery developed (*7*). During the last quarter of the 19th century, Osler (*8*) wrote in 1902, physicians had become better trained and equipped and disease was "understood more thoroughly, studied more carefully, and treated more skillfully." "The average sum of human suffering," he went on, "has been reduced in a way to make the angels rejoice."

The medical officers of World War I had reason to be thankful for these advances, for the wounds they were called upon to treat were far more dreadful than those of any earlier war (*1*). In 1892, the high-powered rifle had replaced the old muzzle loader, and, at about the same time, bullets were developed with thin steel, nickel, or copper jackets. Until World War I, the preponderance of wounds had been caused by bullets and low-velocity missiles. The United States was therefore completely unprepared for the extravagant use of artillery, high explosives, and high-velocity missiles that was manifest soon after the outbreak of the war in 1914. In World War I, about 70 percent of all wounds were caused by high-velocity missiles and high explosives, and their management created new and serious problems.

According to Hoche (*9*), in the 11 million wounds sustained in the armies of the United States, Great Britain, France, and Germany in World War I, there were 660,000 wounds of the chest (6 percent), of which 56 percent were fatal. Hoche's collected figures also show that of 12,350 soldiers killed in action, 20 percent had chest wounds.

The U.S. statistics for chest injuries in World War I are open to some doubt (*10*). In a total of 174,296 injured, 4,595 (2.6 percent) had wounds of the thorax; the case fatality rate was 24.05 percent. The British incidence of chest wounds was 3.8 percent (*11*). Both these proportions are entirely at variance with the incidence of wounds of the thorax in other recorded wars. In the U.S. statistics, it is possible that some wounds of the thorax are included with wounds of the neck and the back, which are listed separately.

In other recorded wars, including World War II, the incidence of chest wounds was about 1:12 (8 percent). In 55,000 wounded in the Seventh U.S. Army in World War II, the incidence of chest wounds was 7.8 percent and the

case fatality rate was 5.4 percent (p. 61). The figures for the Fifth U.S. Army are substantially on the same order. The figures for both armies are for the campaigns of 1944 and 1945, during which the case fatality rate was lower than it was in the early years of the war.

There were no chest centers in the U.S. Army during World War I. Patients with suppurative pleuritis were segregated in a few hospitals, but they were usually cared for in the so-called septic surgery sections. With this possible exception, all chest surgery was performed by general surgeons. At the time, there were only a few surgeons who were qualified in this specialty or who had any interest in limiting their surgical activities to it.

The Allied Experience 1914–17

When the United States entered the war in April 1917, effective methods of treating almost all types of wounds had been established by surgeons of the Allied armies. Among the exceptions were wounds of the chest, about which, as Yates (*7*) pointed out, there were still irreconcilable differences. These differences were caused, he continued, by the failure of many surgeons to understand the interdependence of the functions of the circulatory and respiratory systems; to appreciate the contributions of these functions to the powers of resistance, defense, and repair; and to understand further that these powers must be conserved and developed if immediate recovery were to be facilitated and the extent and duration of subsequent disability were to be reduced. Nonetheless, in spite of this confusion, U.S. surgeons had the general experience of their Allies to build upon when they first encountered wounds of the chest.

The British experience.—Before 1916, according to Gask (*11, 12*), British surgeons practiced a policy of noninterference in chest wounds for three reasons:

1. The experience in the South African War, in which, because the ground was dry and wounds were chiefly caused by rifle bullets, this policy was generally successful.

2. The belief that it would be fatal to open the chest cavity without the aid of some form of pressure chamber.

3. The belief that manipulation of the lung would provoke fast and fatal bleeding.

Experience showed that all of these assumptions were wrong, and by the time the United States entered the war, British surgeons were doing a considerable amount of intrathoracic surgery. First, the need for wound excision (debridement) had been recognized. Later, the need for thoracotomy, at least in some cases, became evident. Surgeons began to lose their fear of the open chest, and their successes further encouraged them to perform many bold and well-conceived operations previously considered impossible. The development of blood transfusion also made them bolder, especially in the management of thoracoabdominal wounds, the results of which, in some hands, showed a great deal of improvement.

Sir Gordon Gordon-Taylor (*13*), however, began his account of chest surgery in World War II with the statement that it was strange that, in spite of the numerous chest injuries encountered, it was not until 27 July 1917 that a memorandum was issued to medical officers of the British Expeditionary Force calling attention to the value of dealing with open pneumothorax by immediate temporary closure of the chest wall by suture. His explanation of the delay was that experiences were disseminated much more slowly in World War I than in World War II.

Until the end of the war, empyema remained the principal anxiety of British surgeons and the principal cause of poor results. During the war, however, the disadvantages of expectant management in many cases of hemothorax, especially those in which clotting and infection were present, had become evident. In 1918, while on a surgical mission to the United States, Grey Turner (*14*) suggested the use of decortication in some cases of old hemothorax, in which, he pointed out, the lung was likely to be found imprisoned in a sort of sheath of organizing blood clots that extended to the diaphragm and interfered with its normal movement. It was most interesting, he continued, to see the lung during decortication reappear "from its coat of mail" and begin to reexpand normally. He "sighed" for anesthetic apparatus that would facilitate the operation by permitting a ready change from ordinary inhalation anesthesia to positive intrapulmonary pressure.

The war left the British, as it did the Americans, a large legacy of patients with chronic empyema, encysted hemothorax, and retained foreign bodies with chronic suppuration, as well as many chest cripples, with rigid and greatly deformed chests.

The French experience.—Before the United States entered World War 1, Pierre Duval (*15*) of the French Army medical service had made some important observations on chest surgery:

The first of these observations concerned the concept, current at the outbreak of the war, that thoracic surgery should not be performed until the casualty had reacted from his initial shock. As a result of this policy, Duval pointed out, the chief causes of death in chest wounds at battalion aid stations were hemorrhage and mechanical asphyxia due to an open thorax. In 3,453 admissions to hospital units in Army areas, the death rate in the most forward units was 45 percent, against an overall rate of 20 percent.

Duval fully realized the difficulty of setting up clear-cut indications for immediate surgery in thoracic wounds, but he nonetheless urged that if signs of hemorrhage were persistent, the wound should be promptly opened and the damage sought for and repaired, whether it was in the chest wall or in the lung. Debridement of wounds of the soft parts and of the extremities was already being practiced with considerable success, and he saw no reason why a contaminated lung and pleura should not be similarly treated. In a series of 500 chest injuries with pneumothorax managed by the usual methods, there were 195 infections. In contrast, in 193 injuries which Duval had handled personally in the Battle of the Somme, there were only 34 infections in the 144

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shell wounds and no infections at all in the 49 bullet wounds. His personal results proved his point that septic sequelae were far more numerous and more serious in wounds caused by high explosives than in bullet wounds, which either were immediately fatal or ran a relatively benign course.

Duval also advocated that all shell fragments and other retained foreign bodies should be promptly removed, under local infiltration with procaine hydrochloride, and that the chest then be tightly closed without drainage. As technique improved, he said, the general surgical principles and practices employed in gunshot wounds were being applied little by little to wounds of the lung. "Let us dare to hope," he concluded, "that those who follow in our steps may soon have many more numerous and more brilliant successes."

The U.S. Experience [1]

General principles and practices.—Patients with uncomplicated chest wounds were not prone to shock unless there was considerable hemorrhage. According to Yates (7), it was often wise to defer transfusion—which was given in small amounts and to few casualties—until after the lung had been reinflated at operation.

All emphasis was placed upon the prevention and treatment of infection, particularly upon its treatment. With respiratory infection so prevalent and the grave type of pneumonia caused by the beta hemolytic streptococcus so frequent (p. 19), this was probably inevitable. Nonetheless, as one looks back now, it is somewhat perplexing that more attention was not directed toward the physiology and the spatial dynamics of the chest.

First aid was limited to hemostasis of the parietal wound, with temporary closure of an open thorax by strapping a firm, thick, broad pad over the wound by means of adhesive tape reinforced by a swathe. This method was preferred to initial suture of the wound, which often resulted in spreading subcutaneous emphysema.

The indications for immediate surgery of thoracic wounds were established as:

1. Aspirating (sucking) wounds.
2. Large retained foreign bodies.
3. Severe bone injury.
4. Complicated lesions of the diaphragm.
5. Extensive hemorrhage and suspected infection, particularly anaerobic infection.

The arguments advanced for the various methods of management of chest wounds in World War I sound much like the discussions in World War II concerning the indications for thoracotomy and the advantages of formal thoracotomy at the site of election versus thoracotomy at the site of the wound.

[1] As a matter of convenience, special types of wounds and special complications of thoracic wounds, including empyema, are discussed under separate headings later in this chapter.

There were four possible methods of treatment, as Yates (7) pointed out in an analysis of a personal series of 104 injuries:

1. *Simple debridement or excision of parietal wounds.*—This method, combined with aspiration or suitable drainage of hemothorax, was a satisfactory routine method of treatment for wounds which were not too serious. Surgery was followed by systematic exercises to produce early and complete recovery.

2. *Limited thoracotomy* (*the traumatic thoracotomy of World War II*).—It consisted of debridement and exploration through the wound of entrance or exit, with little or no enlargement of the traumatic wound. Limited thoracotomy was indicated when the wound was small, the damage slight, and the lung readily inflated. At operation, accumulated blood and fluid were aspirated before closure. Local bleeding could usually be cared for through the same wound, and small wounds of the lung were closed. Missiles were removed whenever it was feasible. If they lay next to large blood vessels, they were always sought for and removed.

3. *Thoracotomy of necessity* (*a term no longer used*).—This operation was little more than a more extensive application of limited thoracotomy. It was used when debridement and limited thoracotomy revealed unexpected lesions that required immediate, more radical intervention. It was used upon casualties who were so severely wounded that both parietal and deep repair had to be managed through a single opening. Its advantages were (1) its greater rapidity and (2) the avoidance of an elective incision, so that the integrity of the parietes was not impaired by the trauma superimposed by such an incision upon the destruction wrought by the projectile. There were also disadvantages, including frequent failure to obtain sufficient exposure for satisfactory intrathoracic surgery, as well as the temptation to escape the risk of an increased surgical mortality by performing an operation less complete than was necessary to obtain complete recovery.

4. *Thoracotomy of election.*—The separate incision afforded sufficient exposure for a satisfactory examination of the pleural cavity and permitted repair of most visceral and diaphragmatic lesions. An elective incision healed well and imposed little disability.

Great importance was attached to prevention of soiling by final, thorough toilet of the pleural cavity and wound. When necessary, the lung was sutured into the defect in the parietal pleura. Blocking of the phrenic nerve with 1 percent cocaine was advised.

A firm and airtight parietal closure was considered imperative in all injuries.

The possibility of tension pneumothorax was recognized in World War I, as was the possibility of rapid collection of fluid with increase in the mediastinal pressure. The nature of acute hematomas of the lung was not, however, fully appreciated. The process was termed "splenization," and resection was the preferable treatment. This method was contrary to the usual practices in World War II, when the pathologic process was more clearly understood.

Generally speaking, when patients were seen early and operation could be performed within 8 hours, the case fatality rate was about 4 percent. When delay was over 24 hours, there was a 10-fold increase in the case fatality rate.

According to Yates (*7*), the use of primary, and even of early, drainage of the pleural cavity after operation was generally condemned, because open methods were employed, and with them, collapse of the lung was inevitable. It was recognized, however, that proper drainage reduced the incidence of empyema; the official history simply states that some type of drainage tube was used, provided with some device to prevent the entrance of air, and that the earlier it was used, the better were the results. It was also pointed out that disastrous pleurisy could be limited if primary drainage were employed for large wounds with open pneumothorax, foreign bodies, and lacerations of the liver and diaphragm. The principle of closed underwater drainage was not as well established, even by the end of the war, as it has since become.

The possibility of postoperative accumulations of serum was realized in World War I, as was their frequency, and routine aspiration was used as necessary as a precaution against this complication. When aspiration was properly employed, the necessity for later open operation was considerably reduced.

Air replacement.—Air replacement as a means of collapsing the lung and thus controlling hemorrhage was first suggested by Chassaignac in a thesis written in 1835. In 1941, Berry (*16*) and Lambert, unaware of the early recommendation, suggested the procedure for uncontrolled bleeding in hemopneumothorax on the basis of their success with it in a personal case. They emphasized that the method had only a limited field of usefulness.

In World War I, artificial pneumothorax was extensively used in Italian military hospitals. The technique had been introduced by Forlanini in Italy and by J. B. Murphy in the United States for treatment of tuberculosis and other diseases of the lung and pleura, and Morelli (*17*), Forlanini's pupil, and Bastianelli (*18*) adapted it to wounds of the chest in which hemothorax was a feature. The routine was to aspirate the chest incompletely and replace the blood withdrawn by air, the amount of air to be injected being determined by readings of intrapleural pressure on a pneumothorax apparatus. If the apparatus was not available, the practice was to replace with air half of the volume of fluid removed. The procedure was repeated in 72 hours and carried out as necessary thereafter to achieve gradual clearing of the chest.

Air replacement was contraindicated in thoracoabdominal wounds. It was also not employed when the injected air would escape through parietal or pulmonary wounds or when it would be difficult to introduce it because of adhesions. Surgery was indicated in these circumstances.

Air replacement never won favor on the medical services of the other Allies, perhaps because, by the time the method had been popularized in Italy, other Allied surgeons were beginning to employ a more aggressive approach in wounds of the chest.

Anesthesia.—The chief reason for the higher case fatality rate in thoracic surgery as compared with the rate in abdominal surgery was the disturbance of the normal intrapleural pressure relations which occurred when air entered through the incision into the chest. Fear of the consequences of an open pneumothorax was the chief reason for delay in the development of chest surgery (*19*).

The solution of the problem of anesthesia for chest surgery began when Meltzer and Auer (*20*) of the Rockefeller Institute introduced their simple method of insufflation intratracheal anesthesia as a substitute for the cumbersome and inconvenient techniques previously used for this purpose. By their method, it was now possible to administer an inhalation anesthetic at the same time that a surgical incision was made into the pleura.[2]

In spite of the simplicity of this method of avoiding collapse of the lung during thoracic surgery, it was employed only infrequently during World War I for three practical reasons:

1. The necessary equipment was seldom available.
2. Few anesthesiologists were familiar with the technique.
3. Few surgeons, as already mentioned, were qualified to undertake thoracic surgery.

Research studies in the American Expeditionary Forces.—In the period between the Château-Thierry operation, in July and August 1918, until after the Armistice on 11 November 1918, a research unit composed of medical officers, nurses, and enlisted men was detailed to various field hospitals and mobile units in zones of active combat (*7*). Its personnel was appointed by the Chief Surgeon, American Expeditionary Forces, and its mission, specified by the Chief Surgical Consultant, American Expeditionary Forces, was in substance as follows:

1. To discover the physiologic interrelationship between the circulatory and respiratory mechanisms, in order to determine the functions which need protection to assure the largest opportunities for immediate and remote discoveries.
2. To develop the simplest effective surgical methods compatible with physiologic requirements.
3. To apply these methods to the wounded whenever there was any possibility of saving life, without regard to the high mortality rate that would inevitably accompany the gravest risks.
4. To follow each fatality with an autopsy, to determine what should not be done.
5. To trace the results in casualties who recovered and thus discover the dependence of degrees of functional rehabilitation upon the methods employed, in order to develop better methods.

[2] This technique, naturally in a cruder form, had been suggested by the late Dr. Rudolph Matas as early as 1900 but had then attracted no attention.

6. To make a final report which would indicate how soldiers suffering from intrathoracic injuries could be more certainly protected against death and disability.

This was a comprehensive mission, and it was undertaken late in the war. In spite of these handicaps, a number of important observations were made:

1. A strong and active individual, with good vital capacity, could survive a wide partial opening in the chest even when it was produced suddenly.

2. A comparable individual, weakened by exhaustion, exposure, hemorrhage, and infection, could scarcely tolerate a small opening.

3. The objective of management should be to protect and restore the function of the external respiration and to assure the integrity of both the circulatory and the respiratory units. This was obviously a difficult task.

4. When surgical procedures were necessary, the respiratory physiology must be understood, and every effort must be made to avoid leaving an open pneumothorax or a pyothorax. These two complications were the principal causes of postoperative disability and death.

5. Differential intrathoracic pressure was necessary for safety during surgery. It was best achieved by the use of a tight-fitting gas-oxygen apparatus such as had been recently developed by Gwathmey.

6. To lessen postoperative discomfort, injection of the phrenic nerve within the chest with 1 percent procaine hydrochloride should be part of each surgical procedure.

7. In the aftercare of the patient, breathing and body exercises should be emphasized, to restore parietal movement, pulmonary elasticity, and normal intrapleural relations.

Thus, as World War I drew to a close, many of the principles of management of thoracic wounds that were to prove basic in World War II were beginning to be developed and understood. In World War II, the emphasis upon chest exercises in the chest centers in the communications zone was regarded as a new and major contribution to thoracic surgery, but, as this record shows, the policy had been developed in World War I. The importance of these exercises had also been recognized in certain civilian centers long before the outbreak of the Second World War. Patients were ambulated early, and exercises were demonstrated to them, though the degree of regimentation possible in the Army, one of the factors which made these exercises so useful in wartime chest surgery, was naturally not achieved in civilian practice.

Postwar conference.—After the Armistice in November 1918, a group of senior Allied medical officers met in Paris for a general discussion of war wounds (*7*). The moderator of the symposium was Brig. Gen. John M. T. Finney, Chief Consultant in Surgery, American Expeditionary Forces. Among the points discussed relevant to thoracic wounds were the following:

1. Col. George Crile, MC, listed hemorrhage, shock, and wounds of the chest as among the conditions making casualties nontransportable. Maj. Gen. Sir Anthony A. Bowlby (British) added that "all completely smashed limbs should never be removed from the field ambulance"; that is, from the installa-

tion which corresponded to the U.S. Army field hospital in World War II. It should be noted that neither authority mentioned thoracoabdominal nor abdominal wounds as contraindications to transportation after wounding.

2. Colonel Crile inquired whether the experience in the Argonne had produced any new data, particularly in connection with shock and hemorrhage. Lt. Col. Walter B. Cannon, MC, mentioned the importance of placing blankets under, as well as over, patients, who lost heat by perspiration and because of their wet clothing and their contact with wet stretchers. He had seen patients in shock with four blankets over them and none under them. The discussion brings to mind similar errors at the front in World War II.

3. Colonel Crile inquired whether morphine was contraindicated in abdominal perforations and in thoracic injuries. Lt. Col. John L. Yates, MC, who was later to write the chapter on chest surgery in the World War I official Medical Department history, replied that in a series of 130 patients with chest injuries, he had seen only 2 upon whom morphine had apparently had a bad effect. He was inclined to think that the bad results in these and other cases could be attributed not to morphine per se but to too much morphine; he suspected that these patients had had earlier injections of morphine that had not been recorded on their cards. He saw no objection to the judicious use of morphine in chest injuries.

Again one is reminded of the World War II experience, in which bad effects arose from the overgenerous administration of morphine and its unnecessary use and not from the drug itself.

4. When votes were taken as to how casualties with through-and-through chest wounds tolerated transportation, the replies were: *badly*, 8, and *well*, 23. A variety of opinions were expressed: *well* after a week; *poorly* if the wounds were caused by shrapnel, but *well* if they were caused by rifle bullets; *well* if the patients had not been operated on and were not in shock; *badly* if the wounds were severe intrathoracic injuries or operation had been performed and healing had not yet occurred.

5. A vote on the comparative status of wounds observed in base hospitals after treatment by various measures favored the following techniques: simple dry gauze, 13; the Carrel-Dakin technique, 12; petrolatum-impregnated gauze, 5. Dichloramine-T, some protective agent, BIPP (bismuth, iodine, and petrolatum paste), flavine, and rubber tubes secured a scattering of votes. Nearly all observers emphasized the risk of packing the wound tightly; lightly placed surface dressings were considered all that was necessary.

6. When the criteria for secondary wound closure (the delayed primary wound closure of World War II) were discussed, all present voted for bacteriologic control plus clinical judgment when both were practical. When they were not, the vote for clinical judgment alone was 10 and for bacteriologic control alone, 5. The optimum period for closure was considered to vary from 3 or 4 days to 10 or 12 days after wounding. Again the discussion is reminiscent of the lessons that had to be relearned in World War II.

7. Indications for thoracic surgery in the forward area were listed as a second chest wound; serious hemorrhage; large effusions; indriven bone fragments; large foreign bodies; a collapsed lung on the same side as the wound; considerable comminution of the ribs; infection; hemothorax with tension; pneumothorax with tension; foreign bodies in the heart, pericardium, or mediastinum; bilateral chest injuries; and anaerobic infection accompanying hemothorax.

8. Indications for operation in the base were listed as empyema; lung abscess; secondary hemorrhage; sinuses caused by foreign bodies; pus pockets; hemothorax with symptoms, which was to be treated by repeated aspirations as necessary; infected hemothorax, for which the treatment was radical thoracotomy.

9. All present voted for thoracic surgery under local infiltration when this technique was possible. When it was not, 18 preferred gas-oxygen anesthesia; 9, ether; 2, chloroform; 3, morphine and atropine; and 1, warm ether.

The symposium closed with a discussion of various techniques of thoracic surgery.

Conclusions from the World War I experience.—Colonel Yates (7), in a detailed analysis of a personally managed series of 104 chest wounds, listed the errors which had been made in them, including failure to appreciate the inherent seriousness of the wound; inadequate preoperative preparation; and a number of unwise surgical procedures. When these cases were analyzed according to the first operation performed, Colonel Yates arrived at the following conclusions:

1. Partial wound excision, usually with paracentesis, is sufficient to protect the least seriously wounded casualties and to hasten recovery without added risk.

2. Limited thoracotomy (p. 11) is applicable to the treatment of less seriously wounded casualties if deep repair can be effected through slight enlargement of the wounds of entrance and exit and if the bulk of a hemothorax can be aspirated by large cannulas introduced through a defect in the parietal pleura.

3. Thoracotomy of necessity, which is a more extensive application of limited thoracotomy, should be used when immediate deep repair is required and when there are reasons for using the parietal wound to secure closure.

4. Thoracotomy of election will find wider application in the future as a primary procedure. If two-stage procedures are practical, it is the preferred secondary procedure. "Indeed," Colonel Yates concluded, "with the development of simple and effective methods of primary drainage, thoracotomy of election may prove to be the safest treatment of massive pneumothorax unless the patient's condition be poor."

At the conclusion of his chapter on thoracic wounds in the official history of the U.S. Army Medical Department in World War I, Colonel Yates made some general observations reminiscent of the observations made by Col. Edward

D. Churchill, MC, Chief Consultant in Surgery in the North African (later Mediterranean) theater in World War II. These observations were embodied in the circular letters issued by the Office of the Surgeon, Headquarters, North African theater and later embodied in War Department Technical Bulletin 147, issued from the Office of The Surgeon General in March 1945 (p. 201).

Success was possible in the management of thoracic wounds, wrote Colonel Yates, if personnel competent to furnish treatment and materials essential for treatment were so organized and disposed that the wounded could be well and properly served. From a medical standpoint, service to the wounded man was all-important. From a military standpoint, service to the fighting man was most important. The exaggerated individualism of civilian surgeons, Colonel Yates continued, led them to misunderstand, or to fail to appreciate, the responsibilities of their colleagues in the Regular service to Army organization and administration. Similarly, medical officers of the Regular service apparently underrated the personal aspirations of physicians and nurses to provide their patients with the best possible care. On both sides, there was lack of preparation to fulfill their obligations, and neither side hesitated, justly or unjustly, to hold the other side responsible for its own deficiencies.

Colonel Yates concluded:

> An Army must be an autocratic organization, but many evils peculiar to autocracies can be minimized. This can be accomplished effectively so far as the Medical Corps of the U.S. Army is concerned by developing cooperation in advance. Civil surgeons can and should prepare themselves not merely to give professional services but to give them under the restrictions of military methods, the worst attribute of which is inflexibility. Similarly, the officers of the Regular Medical Corps, kept directly in contact with progress and changing requirements of surgical practice, will find more liberal interpretation of regulations, which are fixed products of past experiences and often are literally opposed to immediate necessities. National security should be enough of an incentive to produce the necessary personal adaptation and coordination of effort.

As experiences in a later war were to prove, there is no category of wounds to which these generalizations are more applicable than wounds of the thorax.

EMPYEMA IN WORLD WAR I

In World War I, the U.S. experience with thoracic conditions was concentrated chiefly upon the treatment of infection, and, more specifically, upon the treatment of the infected pleura (*21*). This was partly because of the numerous epidemics of measles and pneumonia that occurred in camps after this country entered the war and partly because of the worldwide epidemic of influenza and pneumonia in 1918 and 1919.

In the voluminous literature on empyema that appeared after World War I, very little attempt was made to separate posttraumatic organizing hemothorax and subsequent hemothoracic empyema from metapneumonic or synpneumonic empyema, in spite of the significant differences between the two groups of cases. The explanation, advanced by both British and U.S. surgeons

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in World War II, is probably that the influenzal empyemas so overshadowed the traumatic variety in both numbers and importance that the separate identity of the posttraumatic variety was not realized. It is remarkable, nonetheless, that these differences were not more clearly appreciated by the military surgeons who had observed the large numbers of empyemas during World War I.

The Empyema Commission

During the second half of 1917, pneumonia, in part primary and in part secondary to measles, was causing approximately 65 percent of all deaths in the U.S. Army. The Surgeon General, in an attempt to find some means to combat this terrible loss of life, appointed a commission to study pneumonia in its clinical, pathologic, and bacteriologic aspects. One of the far-reaching results of the work of this commission was the determination that the beta hemolytic streptococcus was playing the principal role in many cases of pneumonia and was giving rise to an entity which the commission termed interstitial bronchopneumonia.

Because empyema constituted such an important complication of pneumonia, especially when the pneumonia was of the hemolytic streptococcic variety, The Surgeon General, in the early spring of 1918, created another commission to take up research work where the first research commission (p. 13) had left off. This commission, later known as the Empyema Commission, carried out its work at Camp Lee, Va. It had two groups of members. The continuous members were Maj. Edward K. Dunham, MRC; Maj. Evarts A. Graham, MRC; Maj. James F. Mitchell, MRC; Capt. Alexis V. Moschcowitz, MRC; Maj. Ralph A. Kinsella, MRC; Capt. Richard D. Bell, MRC; and Lt. Franklin A. Stevens, MRC. The temporary members were Capt. William L. Towers, SC; Capt. Clifford C. Hartman, MRC; Lt. Frederick D. Zeman, MRC; Lt. Milton B. Cohen, MRC; Miss Maude H. Hays, dietitian; Miss Bessie E. Stocking, artist; and Miss E. Pauline Jacobs, secretary.

When the Commission began its work, there were two major problems to be solved. The first, as already mentioned, was the development of empyema as a sequel to the pneumonia that was itself a sequel of measles, meningitis, and influenza. The second problem, which was extremely acute, was the prohibitively high case fatality rate associated with the standard routine of early operation as soon as empyema was diagnosed.

Immediate problems.—The management of empyema had been a subject of discussion for many years before World War I. Arguments were heated and acrimonious, with the protagonists of one method or another holding firmly to their opinions. One group defended early operation. Another group held out just as stoutly for repeated aspiration or aspiration and pneumothorax. Roe (*22*), in England, for instance, recommended paracentesis thoracis as a curative measure in both empyema and "inflammatory hydrothorax." In

the United States, Bowditch (*23*) of Boston, in 1852, had urged that pleuritic effusions be managed by repeated aspiration.

When the United States entered World War I, early operation was routine in empyema that developed after the stage of resolution of pneumonia had begun. The infection was usually pneumococcic in origin, and the pathologic process found at operation was characterized by walled-off cavities of varying sizes filled with thick pus. The surgeons of World War I, who were chiefly conversant with this type of empyema, had either forgotten that beta hemolytic streptococcic empyema also exists or had failed to recognize the differences between it and the pneumococcic type. The differences were considerable. The hemolytic streptococcic type developed very early, sometimes concomitantly with the pneumonia itself. It was characterized by the presence of large quantities of thin, purulent fluid, which accumulated rapidly. Most important, the walled-off cavities that were characteristic of pneumococcic empyema were completely absent; in the early stages of the beta hemolytic streptococcic variety of empyema, there was no attempt at walling off at all.

One reason that empyema was so dreaded by most surgeons was their lack of understanding of the pathologic process and its correction. As a result, drains were incorrectly placed. Drainage tracts were permitted to close too soon. Some surgeons followed the example of Mozingo (*24*), who believed, as was later proved false, that a cavity could be sterilized and then left alone with its residual pneumothorax.

For all of these reasons, empyema was often allowed to become chronic, and patients drifted from one clinic to another. No thought was given to physiotherapy or to early ambulation and active exercise, to help the lung reexpand and prevent a shrunken, deformed, and stiff chest. When the errors and misunderstandings associated with empyema in civilian practice were carried over into wartime practice, the results of management were intolerably bad.

Physiologic Concepts in World War I

Early in World War I, the physiologic concepts of the respiratory mechanism were surprisingly erroneous (*19*). The prevailing belief was that the mediastinal pleura constituted a more or less rigid partition between the two pleural spaces, so that the result of an open pneumothorax would be the collapse of the lung of the affected side, without any effect at all on the opposite, uninvolved side.

More important than the error of this concept was the significance read into it, that the former fear of a pneumothorax associated with intrathoracic surgery was groundless, since the worst that could happen would be the temporary collapse of a single lung. Many experienced surgeons removed shell fragments from the lung without any special equipment for combating the effects of pneumothorax, and in their astonishment over the survival of their

patients, they drew extravagant and unwarranted conclusions from their results. One of these conclusions was that no special protection was necessary against the effects of pneumothorax. Duval of the French Army and Moynihan of the British Army, both highly experienced and capable surgeons, said Graham, helped to create the dangerous impression that operations on the chest could be performed quite as safely as abdominal operations, without heed to any possible complications from pneumothorax. Duval (*15*) stated unequivocally that it was quite as safe to handle the lung and operate on it at thoracotomy as it was to handle a coil of intestine and operate on it at laparotomy. Surgery of the lung, he remarked, "does not require any of those pressure chambers which the genius of the Germans invented and their persuasion made us think necessary."

As Graham (*19*) pointed out in his 1957 review of the development of thoracic surgery, an accurate knowledge of the effects of pneumothorax was considerably more than an academic matter. It was a requirement of fundamental importance. The full development of chest surgery, including the management of empyema, was impossible until this knowledge was available and fully utilized. It was the comprehension of the importance of respiratory physiology that so sharply differentiated the practices and results of chest surgery in World War I and World War II (p. 198).

Work of the Empyema Commission

The experimental work on dogs carried out at Camp Lee, under the direction of Major Graham and Captain Bell, included studies on the comparative physiology of animals and humans; studies on pneumonia and empyema in both species; and studies on normal and diseased animals when the intact chest and the open chest were filled with sterile fluids and infected fluids.

Changes of concept.—As the result of these studies, the following conclusions on pneumothorax were possible:

1. In a normal chest, in which there is no thickening of the mediastinal pleura, alteration of the pressure in one pleural space produces almost the same alteration in the contralateral space. It could be concluded, therefore, that an open pneumothorax on one side affects the other side also, though not quite to an equal degree.

2. The lethality of an open pneumothorax depends upon its size and the vital capacity of the patient, just as the research unit operating in Europe had also demonstrated (p. 14). A unilateral pneumothorax would be fatal if the opening were beyond the size which the vital capacity of the patient could withstand. If his vital capacity were high, a much larger opening could be withstood than if it were low. If the vital capacity were so greatly reduced that its level approached that of the vital air requirement, then a very small, unilateral opening could be fatal.

Practical application.—The conclusions derived from the experimental work of the Empyema Commission had immediate practical applications. At

this time, an epidemic of acute streptococcic empyema was raging in U.S. Army camps. The usual method of treating it was to resect a rib and establish open drainage of the involved pleural space as soon as the diagnosis was made. The case fatality rate averaged 30.2 percent and was as high as 90 percent in some series. The principal cause of death, the studies of the Commission showed, was open pneumothorax, created by surgical means during the period of acute pneumonia. Operation was being done on patients whose vital capacity was already seriously lowered by their pneumonic disease. It was still further lowered, sometimes to the lethal level, by the establishment of an open pneumothorax.

The policy recommended by the Commission was:

1. Careful avoidance of open pneumothorax during the active period of the pneumonic disease.
2. Early sterilization and obliteration of the empyema cavity.
3. Maintenance of the patient's nutritional status.

By this policy, simple aspiration every 3 or 4 days was substituted for surgery during the acute pneumonic stage, or closed drainage was instituted. The object of treatment was to prevent fluid accumulations from becoming large enough to cause dyspnea. Even before the Commission had advocated this policy, it had become evident in some civilian hospitals that these patients did better under repeated aspiration or with closed techniques of drainage than by early, open drainage, but it was not until the work of the Commission was published that the rationale of the improved results became clear.

When the purulent exudate had become thick, when recovery from acute pneumonia had occurred, and when the empyema could be presumed to be localized, open drainage, usually with rib resection, could safely be performed. As a rule, these criteria could be met in about 10 days. By delaying the institution of open drainage until the pus had become thick, the surgeon made his opening into an abscess cavity instead of into the free pleural cavity. By the delay, the harmful effects of open pneumothorax were avoided in patients who, because of their extensive pneumonic process, were already dyspneic and often cyanotic. If a little air entered the pleural cavity when deferred surgery was instituted, it did little harm then because, with the clearing of the pneumonic process, the vital capacity had increased. Furthermore, the mediastinal pleura had become stabilized as the result of edema and inflammatory induration, and it was therefore less likely to be crowded over into the contralateral pleural cavity and to compress the lung on that side.

When the new plan of management became generally effective, results promptly improved. At Camp Lee, for example, the case fatality rate fell from 40 percent to 4.3 percent. At Fort Riley, Kans., Maj. William J. Stone, MC, chief of the medical service and in charge of the pneumonia wards, reported convincing comparative figures: In a series of 85 patients with empyema treated by the old plan of early, open operation, the case fatality rate was 61.2 percent. In a second series of 96 patients treated by early aspiration and late surgery,

the case fatality rate was 15.6 percent. In a third, later series treated by the same methods, the case fatality rate was 9.5 percent.[3]

Chronic Empyema

There is no doubt that the majority of cases of chronic empyema that were the residua of World War I were the result of ill-timed and poorly planned early management. Col. William L. Keller, MC (*25*), reporting on a large series of patients observed after the war, found that 75 percent had "accessory" pockets of infection; 15 percent had foreign bodies in situ, including drainage tubes and bismuth paste; and 90 percent had osteomyelitis of the ribs. Beta hemolytic streptococcus had been the infecting agent in this series, and in most cases, drainage had been instituted too early, before localization had occurred. Many patients therefore developed total empyemas, the majority of which were inadequately drained, and, as a result, residual pockets of infection formed and persisted.

Three types of operations had been developed to deal with these chronic empyemas:

1. In 1879, Estländer (*26*) recommended removal of the ribs overlying the pleural cavity. This operation was essentially a limited extrapleural thoracoplasty.

2. In 1890, Schede (*27*) went one step further and recommended the removal of the tough, edematous fibrous pleura overlying the pleural cavity along with the ribs.

3. In 1893, Fowler (*28*) in the United States and Delorme (*29*) at the Val-de-Grâce Hôpital in Paris recommended that chronic empyema be managed by decortication. This operation, which became the preferred surgical treatment for organizing hemothorax and hemothoracic empyema, is discussed in detail elsewhere (p. 24).

Tuffier's (*30*) personal statistics for these operations in World War I were as follows:

1. When the Estländer operation was used, the case fatality rate was 18 percent: 50 percent of the patients were classified as cured and 32 percent required additional surgery.

2. When the Schede operation was used, the case fatality rate was 28 percent and 50 percent of the patients were cured. The remainder were not followed.

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[3] Dr. Berry writes of these matters from personal experience. In April 1918, just after he had entered the Army, he was assigned to the hospital at Fort Riley. Here he worked under Major Stone and also served as assistant to Maj. George Draper, MC, of New York City. Major Draper was then studying the bacteriology and epidemiology of pneumonia and meningococcic cerebrospinal meningitis both at the Fort Riley Hospital and among the troops of the 89th Division in training at nearby Camp Funston. Dr. (then Lieutenant) Berry's work was done in the laboratory under the immediate tutelage of Dr. Edward C. Rosenow, one of the most distinguished bacteriologists of the time, who had been asked by the Army to work as a civilian on the problem of hemolytic streptococcus in milk and other dairy supplies and food, as well as among human carriers.—J. B. C., Jr.

3. When the Delorme operation was used, the case fatality rate was 15 percent and 48 percent of the patients were cured. The remainder were not followed.

Both the Estländer and the Schede operations had many disadvantages. They left considerable deformity. They were attended with considerable risk. The chest was always infected. The postoperative course was long and trying. The surgery necessary required patience, tact, and a profound knowledge of surgical principles as well as a clear understanding of respiratory physiology. Colonel Keller (*25*), at Walter Reed General Hospital, Washington, D.C., made outstanding contributions to the courageous and successful treatment of many of the empyema casualties of World War I.

Hemothoracic Empyema

In World War I, aspiration was favored as the initial treatment of hemothorax; it led to early recovery and return to duty. The bad results of organized hemothorax were realized, as was the fact that infection could be anticipated in 25 percent or more of all such cases. As the war progressed, therefore, there was growing agreement that in cases of massive clotting, thoracotomy, with mechanical cleansing of the pleura and tight wound closure, was the procedure of choice. It was carried out by three methods:

1. Mere debridement of the wounds of exit and entrance.
2. Formal thoracotomy at the site of election, with the repair of wounds of entrance and exit.
3. Removal of foreign bodies, with resection and suture of the lung according to the indications.

Also as the war progressed, postoperative airtight drainage came to be considered better than repeated aspiration, and early ambulation and activity were recommended. Thus at the end of World War I, there existed the prototype of the methods of treatment of hemothorax and organizing hemothorax used with such brilliant results in World War II.

Many observers in World War I recognized that the late results of an inadequately treated or neglected hemothorax could be extremely serious. They included pulmonary compression, thickening of the pleura, immobility of the diaphragm, poor pulmonary expansion, shoulder drop, scoliosis, and dyspnea (which might be incapacitating).

The dangerous possibilities of secondary infection of hemothoraces were also recognized. Soltau (*31*) reported the presence of gas-producing organisms in 48 percent of infected cases and of streptococci in 40 percent. The seriousness of these observations is apparent when it is recollected that 75 percent or more of wounds of the chest were associated with hemothoraces.

Hemothorax associated with thoracic injuries provided all the conditions favorable for pleural infection. They included lacerated tissue, the unyielding costal parietes, exudation that was more rapid than compensatory absorption

(with resulting increase in the hemothorax), and the presence of retained foreign bodies and of bacteria. The presence of blood in any amount was irritating and could lead to a serofibrinous serositis. With the development of hemothorax, the blood was defibrinated by the physiologic movements of the chest, and the fibrinous exudate spread over the entire pleural lining. Infection readily followed.

When an acute pyothorax was added to the burden of recent wounds and exposure, it became an extremely serious complication, particularly when, as often happened, the casualty could not receive the personal, individual attention he could have received in civilian life. Chronic pyothorax, even when it was treated as superbly as it was by Colonel Keller, inevitably caused material disability.

DECORTICATION IN EMPYEMA

Development of Operation

Numerous observers, beginning with Laennec, had noted that in chronic empyema, the lung beneath the thickened membrane was often normal and that its reexpansion was often prevented not by pulmonary disease but by a false membrane deposited on the pleural surface.

Delorme (*29*), in 1893, was the first to make practical application of this observation in a "tuberculous" abscess of the chest wall with intrapleural extension. The operation consisted of the removal of two ribs and of the thickened membrane overlying the parietal pleura and the lung. The next year, at autopsy, he removed a leatherlike membrane from the lung of a patient who had had tuberculous pleurisy for 6 months and had died after rib resection. When the membrane was removed, the underlying lung was found healthy and expansile.

Delorme's first decortication for empyema was performed in January 1894 (*32*), on a patient who had been ill for 4½ years. The case was apparently highly favorable because, as he described the operation, as soon as the peel was split, the lung began to burst forth, much as the pulp of an orange appears when it is peeled, and full pulmonary reexpansion occurred. The end results were excellent. Two years after he had performed the operation, Delorme applied the term "decortication" to it (*33*).

Although Delorme devised the operation of decortication, he was not the first to employ it on the indication of empyema. This distinction belongs to Fowler (*28*), who performed the operation in 1893, in line with his contention that the fibrous investment of the pleura in chronic suppurative disease must be removed before pulmonary expansion could be achieved. His patient, a 35-year-old woman, had been ill with empyema since January 1891; five thoracenteses and open drainage had all been unsuccessful. The mass of cicatricial tissue which he dissected free from the thoracic wall, diaphragm, pericardium,

and lung occupied three-fifths of the right pleural cavity. Within 28 days, the lung had completely reexpanded, and the good results led Fowler to suggest the possibilities of this method for other instances of old empyema that had resisted the means ordinarily employed for their cure.

Delorme clearly described the pathologic process in chronic empyema as a "shell" or "false membrane," and neither he nor Fowler mentioned the removal of thickened pleura in their reports. It is odd, therefore, that the totally erroneous idea soon developed that decortication was the removal of thickened pleura. This incorrect concept persisted in many quarters until World War II. The term "pleurectomy" was, in fact, employed by C. H. Mayo and Beckman (*34*) in 1914 and by Newton (*35*) in 1916. On the other hand, Dowd (*36*), in 1909, stated that the firm exudate in empyema became so incorporated with the pleura that the resulting membrane resembled a thickened pleura, and the pathologic process was also correctly conceived of by Lilienthal (*37*) and by Spencer (*38*) in 1915, by Grey Turner (*14*) in 1919, by Moynihan (*39*) in 1920, and by Graham (*40*) in 1924.

Indications and Results

In spite of the unquestioned soundness of the concept of decortication, the operation never became widely popular until World War II. Its dangers, which were real enough, were overemphasized, and although some surgeons advocated it on strict indications, others would have nothing to do with it.

Delorme (*41*), in 1912, had pointed out that patients with posttraumatic empyema were particularly favorable candidates for decortication. Grey Turner (*14*), in a postwar discussion of chest wounds, described empyema following hemothorax as more serious than the empyema seen in civilian practice, and for this reason he considered drastic measures such as decortication more justified in its management. Moynihan (*39*), among others, emphasized the importance of freeing the lung from constricting adhesions when thoracotomy was performed for the removal of missiles; he thought, in fact, that many times liberation of the lung was more important than the removal of the foreign body.

Decortication was mentioned in the report of the Empyema Commission in World War I (*21*), but the members had no great enthusiasm for it. Their remarks, in substance, were as follows:

This operation, like the Estländer and Schede operations for empyema, carries a high mortality rate, and the patient who submits to the serious risk which it entails has little assurance of complete relief. Extensive decortication is usually attended by serious hemorrhage. In many instances, a complete operation is impossible because the fibrous tissue on the surface of the lung is only part of a more general fibrosis of the whole lung, and projections of scar tissue extend from the surface deep into the lung substance. Colonel Keller (*25*), in 1922, made much the same point. He considered decortication suitable

for some patients, but he qualified the recommendation with the sound warning that nothing could effect reexpansion of a lung which had become fibrotic.

The Empyema Commission recognized the benefits of chemical decortication with Dakin's solution in some cases of empyema, and Gurd, in a discussion of the operation at the 1946 meeting of the American Association for Thoracic Surgery (*42*), recalled that this technique had been used successfully by British surgeons in World War I when hemothoraces could not be evacuated by aspiration. Gurd also mentioned that during World War I, he and some of his associates made it a practice, when they were operating for empyema, to remove a fragment of rib sufficiently large for the hand to be introduced into the chest, so that what amounted to a very early decortication could be carried out with sponges.

It was entirely logical that decortication should not have attained wide popularity when it was first introduced:

1. The operation was usually performed only on poor risk patients, who had been ill for months or years.

2. The long duration of hemoorganization or suppuration had usually resulted in enormous thickening and organization of the visceral pleura, while formation of fibrous synechiae between the constricting membrane and the pleura had resulted in such a degree of cellular intimacy between the pleura and the investing layer of organized exudate that the operation was almost doomed to failure when it was undertaken. In addition, the lung had frequently become fibrotic.

3. If a complete operation was attempted in the face of these conditions, dangerous hemorrhage could result, or bronchopleural fistulas might follow. Complete operations were therefore not the rule. Usually, only the outer surface of the lung and the fissures were liberated. No attempt at visceroparietal, mediastinal, or pericardial separation was made. A compromise operation was sometimes employed, consisting of deep crosshatching over the thickened visceral pleura, sometimes with liberation of the lung along with the circumference of the cavity, the patch of thickened pleura over the cavity being left intact. This operation was sometimes combined either with a thoracoplasty or with a Schede type of operation, with removal of the overlying parietal pleura.

4. Anesthesia for chest surgery was entirely inadequate.

5. Blood transfusions were seldom employed.

6. Chemotherapy and antibiotic therapy were not available, and surgery in the presence of fresh suppuration was therefore particularly hazardous.

As a result of these unfavorable conditions, the case fatality rate in decortication was high. The statistics which Violet (*43*) collected in 1904 covered 160 operations. Although 41.9 percent of the patients were entirely well and 12.5 percent improved, the case fatality rate was 12.5 percent. In 1915,

Lilienthal (*37*) reported 23 decortications on patients ranging in age from 16 months to 53 years. There were 18 cures, but there were also 4 deaths.

Hedblom (*44*), in 1920, reported on 30 of 150 patients with empyema treated by decortication, with 1 hospital death; 3 later deaths from other causes; 15 primary cures; and 5 additional cures after secondary operations. At the time of the report, three patients had persistent sinuses, and three were still under treatment.

By far the best results reported for decortication before World War II were by Eggers (*45*) in 1923, 146 operations with only 5 deaths (3.4 percent).

Decortication in World War II

As these various facts show, decortication was an operation whose real potentialities were not fulfilled when it was first introduced, in World War I, or in the interim between the wars. Not until the North African campaign in World War II was it finally appreciated that infection of the pleura in an otherwise healthy chest, most often from a neglected hemothorax with clotting and organization, was entirely different from empyema resulting from disease within the lung; that is, pneumonia. In July 1943, at the chest center established by Colonel Churchill at the 53d Station Hospital, Bizerte, Maj. Thomas H. Burford, MC, performed the first decortication, with strikingly successful results.

The idea of decortication in organizing hemothorax came to him, Major Burford related, not because of the past record of the operation but from the British operation known as "turning out the clot." This procedure was used in hemothoraces in which aspiration, for one reason or another, was not satisfactory. After the patient had been stabilized to the point at which mediastinal shift was unlikely, a limited thoracotomy was done, the clot was scooped out, and drainage instituted.

The firmness of the exudate or peel, which the British repeatedly emphasized, led Major Burford to speculate that it might be worthwhile to cut through it and see what lay underneath. He had the opportunity at the chest center in Bizerte when two patients with organizing hemothoraces of almost precisely the same degree came under his observation. He used one of them, an American soldier, as a control, treating him by the standard routine. The other patient, a German prisoner of war, was treated by thoracotomy and decortication. A small incision in the pleura revealed that it was entirely normal. When the incision was extended, normal lung, to the surgeon's surprise and delight, herniated through the opening. The peel was then pulled off the lung, just as one would pull off a glove. The patient made an excellent recovery.

After this demonstration, decortication was brilliantly developed in the North African theater by Major Burford, Maj. (later Lt. Col.) Paul C.

Samson, MC, and their associates. It proved not only safe but strikingly successful in the management of organized hemothorax and hemothoracic empyema. The optimum time for its performance was within 3 to 6 weeks after wounding. At this time, there were few organizing adhesions between the overlying exudate or peel and the underlying healthy lung. It was therefore possible to strip off the peel, with complete reexpansion of the lung, just as Delorme had observed this phenomenon when he introduced the operation 50 years earlier.

THE PERIOD BETWEEN THE WORLD WARS

There were three reasons for the founding of the American Association for Thoracic Surgery in 1918, (1) the awakening realization of the importance of chest physiology, (2) the work of the Empyema Commission, and (3) the development of surgery for pulmonary tuberculosis. The major portions of the first programs of the association were occupied with problems of empyema and tuberculosis.

At this time, acute empyema and chronic empyema were both so common and so much a part of general surgical practice that it was seriously debated whether this condition should even be included in thoracic surgery. During the years between the wars, unfortunately, the lessons of World War I that were so ably recorded in the official medical history of the war were forgotten. Until the advent of the sulfonamides in the late 1930's, chest surgeons continued to concern themselves with the management of empyema by aspiration, closed drainage, various techniques of irrigation, and open thoracotomy, as well as with collapse operations for chronic empyema.

Hemothorax was not a major problem in civilian injuries of the lungs and pleura, which were chiefly crushing or were caused by bullets or small weapons such as ice picks. Carnes Weeks (*46*), a surgeon for the New York Police Department, from his experience with a small group of patients with bullet wounds of the chest, recommended prompt evacuation of hemothoraces, to permit reexpansion of the lung and to avoid protracted invalidism.

By the end of the period between the World Wars, whole blood transfusions were being freely used in civil practice. The significance of Robertson's (*47*) work in World War I, however, had not been read aright, and the profession had been lulled into a false sense of security by erroneous concepts of blood substitutes. Therefore, as the United States entered the war, the entire emphasis was upon plasma and the so-called blood substitutes, and no preparations were made for the use of whole blood in quantity, upon which, during the war, the chief emphasis was to be placed for resuscitation and for preparation for surgery.

During the period between the wars, there was a dramatic development in thoracic surgery. This was partly from the impetus received in this field during World War I and the return to civil life of young surgeons who

had seen the possibilities in it. Also during this period there were enormous advances in anesthesia for chest surgery. In addition, and perhaps most important of all, interne and residency systems in the United States were developed, and many young thoracic surgeons were well trained and ready to take over where their pioneering predecessors had left off.

The United States was catapulted into World War II, in which it fought in three major theaters, each of which, in turn, produced its own peculiar diseases and problems. By this time, preventive medicine was a highly developed specialty. In World War II, therefore, there were no serious epidemics in military camps in the United States, as in World War I, nor was there a worldwide epidemic of influenza. Pneumonia had been on the decline for many years, and the sulfonamides, and later penicillin, were available as powerful therapeutic agents. As a result, infection was never a serious problem, and attention could be focused upon (1) the proper surgical treatment of wounds by methods that rested upon a sound anatomic and physiologic basis, and (2) early wound closure, with restoration of as nearly normal function as possible.

It was realized from the beginning by the theater consultants in surgery (Colonel Churchill in the Mediterranean theater, and Col. (later Brig. Gen.) Elliott C. Cutler, MC, in the European theater) that adequate initial surgery furnished the surest means of preventing infection. It was also promptly recognized by them that plasma was not an adequate substitute for blood, which was provided and utilized in steadily increasing quantities.

In the Mediterranean theater, under the guidance of Colonel Churchill, the attention in chest wounds was centered on the status of the lung rather than, as in World War I, upon the pleural space. The physiologic disturbances incidental to wounding, which required prompt treatment, were managed in the most forward hospital unit, sometimes by very simple measures, sometimes by extensive surgery. Emphasis was placed upon adequate resuscitation, measures to secure prompt reexpansion of the lung, and rehabilitation. Chest centers for expert reparative surgery and convalescent care were established in the communications zone.

As a result of the principles and policies developed for their management, empyema and other complications of chest wounds were relatively infrequent, and the mortality rate was surprisingly low. The treatment of these wounds probably reached its zenith in the period extending from the spring campaigns of 1944 to the end of the war. The explanation is obvious: Blood banks were established in all theaters of operations and in the United States, to supply blood for oversea use. About this time, penicillin (figs. 1 and 2) became available in quantities sufficient for general use. Perhaps most important of all, the personnel of hospitals and auxiliary surgical groups now included large numbers of well-trained thoracic surgeons who had not only profited by their training and experience in the United States but who were also veterans in the surgery of combat-incurred chest trauma.

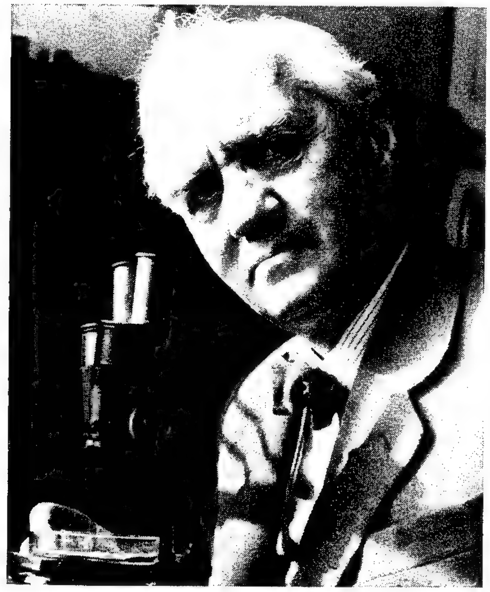

FIGURE 1.—Sir Alexander Fleming, who discovered penicillin in 1928.

FIGURE 2.—Sir Howard Florey, who took up Fleming's work and extracted the essential compound from the liquid in which penicillin grows.

BRITISH CHEST SURGERY IN WORLD WAR II

By 1939, when Britain entered World War II, there were a number of favorable circumstances in the management of war wounds (*13*, *48*). Gordon-Taylor (*13*) listed them as follows:

1. Important information concerning combat-incurred chest wounds had been gained by the observation and secondary treatment of the pensioners

of World War I. A great deal had thus been learned about the late results of retained foreign bodies, imperfectly treated hemothorax, and the management of chronic empyema.

2. The technique of anesthesia for chest surgery was well developed.

3. The importance of blood replacement was realized, and blood banks had been established.

4. One-stage lobectomy had been introduced, and radical chest surgery of an extent that had previously been impossible was now feasible.

5. The importance of physical therapy and active chest exercises, to prevent deformity and respiratory impairment, had come to be realized.

6. Thoracic surgeons had been trained in increasing numbers in recent years. This group, together with the residue of chest surgeons who had gained their experience in World War I, provided a nucleus of competent thoracic surgical personnel for both the Armed Forces and the special Emergency Medical Service centers in the United Kingdom.

The British also had excellent equipment for thoracic surgery, which was looked upon with envy by U.S. chest surgeons in the early days of the war, before their own equipment reached the optimum quantitative and qualitative levels later attained. Before this desirable situation developed, the generosity of the British War Office made it possible for U.S. surgeons to obtain a good deal of much needed equipment.

Administrative Considerations

The British Medical Service had a civilian consultant in chest surgery, Mr. A. Tudor Edwards, but had no Army consultant in this specialty. The greatest number of chest injuries incurred in combat were not handled in Army installations but in the Emergency Medical Service centers in the United Kingdom. Mr. Tudor Edwards controlled their organization, which was based on a regional system. Some regions, because of shortages of specialized personnel, were undesirably large. Surgeons attached to various hospitals often acted as consultants for much larger areas.

These centers continued the primary treatment initiated by Army surgeons and cared for practically all casualties with chest wounds returned to the United Kingdom. The period between the outbreak of the war and the heavy fighting in May 1940 provided the opportunity for them to become well organized and highly developed. They were therefore in an excellent state of readiness when the first battle casualties began to arrive in May 1940 and when the enormous numbers were received shortly afterward from Dunkirk. In the emergency, the chest centers could not limit their admissions to thoracic casualties, but the attempt to direct all chest casualties to them was generally successful.

Soon after the British entered the war, plans were made for the formation of special chest units, but they had not been implemented by the time of the

Battle of France. Two small surgical chest units, which were later organized for service in the Middle East, worked in Italy, and two similar units were established after the Normandy landings. No special provisions were made for chest surgery in Burma, but a unit was preparing to go to India when the war ended.

Clinical Considerations

Air-raid casualties.—The British learned a great many lessons from the casualties of air raids, both before Dunkirk and during the entire war. There were exceptional opportunities for early treatment—much earlier than was possible under battlefield conditions—because the injuries so often occurred in close proximity to hospitals. Many casualties survived who might not have lived had they sustained similar injuries in the field.

During the air raids, even very severely wounded casualties were often treated by primary thoracotomy, with complete wound excision, evacuation of hemothorax, and resection of damaged lung, and were discharged from the hospital within 3 weeks.

Crushed and so-called stove-in chests were frequent, from falling masonry and from traffic accidents in the blackout, as well as from bomb injuries. Paradoxical respiration, a serious feature of these injuries, was easily controlled by effective strapping over a pad laid over the damaged portion of the chest.

Two complications were characteristic of air-raid injuries. One was severe, acute dilatation of the heart, which occurred so rapidly that in some of the earlier cases, before its importance was realized and a routine of treatment adopted, the casualty did not survive. The second was the accumulation of tracheobronchial secretions (the wet lung of U.S. surgeons), which had to be evacuated promptly to prevent purulent bronchitis, atelectasis, and fatal pneumonia. Bronchoscopy was employed if simpler methods, including catheterization, did not achieve prompt results.

Combat casualties.—In the period before Dunkirk, the British, according to their official history (*48*), made many errors in the management of chest injuries because they ignored the principles of primary wound management that they should have known well. Almost all casualties who received initial wound surgery underwent wound repair without wound excision or provision for drainage. When they were received in the British Isles, almost every wound thus treated was heavily infected, and many patients were seriously ill with intrathoracic infections. Ironically, many casualties who had received only first aid, with the simple application of a field dressing, were in much better condition and presented no such sepsis as has just been described. Men who had been left untreated on stretchers for 3 or 4 days because their injuries seemed so severe that treatment was not considered practical owed their lives to the fact that their wounds had not been sutured.

These patients with severe intrathoracic infections required weeks and months of treatment. They demonstrated again the importance of correct

initial wound surgery and the risk of suturing an unexcised or imperfectly excised chest wound.

In the North African theater, the British chest surgeons, like U.S. medical officers, learned the important lesson that war wounds of the chest must be treated in two phases:

1. Patients with gross disturbances of the cardiorespiratory system furnished the real emergencies of traumatic chest surgery. If these physiologic derangements were not promptly corrected, they could be fatal. Initial treatment must therefore consist of standard resuscitative measures, including the administration of blood and oxygen, closure of a sucking pneumothorax, and correction of mediastinal displacement by early aspiration of air and fluid.

2. The second phase of management consisted of measures to prevent infection, or its treatment if it had developed. These procedures included repeated aspirations of the chest by needle, or by major thoracotomy if aspiration failed, decortication as indicated, and the institution of physiotherapeutic measures designed to encourage normal breathing and prevent thoracic deformity. The prewar concept that wounds of the lungs would be widely excised or even treated by lobectomy was not put into practice. D'Abreu, in fact, knew of only one lobectomy performed in Italy. The U.S. experience was much the same (vol. II, ch. I).

Hemothorax and hemothoracic empyema.—As the British experience progressed, certain facts concerning hemothorax and subsequent empyema became evident:

1. Clotting could be expected in from 5 to 10 percent of all hemothoraces. The U.S. experience pointed to a somewhat higher incidence.

2. The incidence of clotting was increased by inadequate or delayed aspiration.

3. Clotting was more likely to occur when thoracic damage was considerable. The theory that thromboplastic substances were liberated in severe injuries and that clotting was increased in this variety was supported by the observation that it was much more frequent in massive damage produced by a rapidly moving bullet from a rifle or a machinegun. It was thought possible that the presence of *Staphylococcus aureus*, which produces no fibrinolysin, might play a part in the incidence of clotting.

The British recognized three stages or forms of clotted hemothorax:

1. Multiple pockets containing air and fluid demonstrable on roentgenograms and associated with major degrees of pulmonary collapse. At operation in these cases, fluid was found entrapped among masses of organized or organizing fibrin.

2. Massive blood clots, which really represented a pleural hematoma rather than an organizing fibrinothorax and which required prompt removal. These patients had higher fever than was present in patients with the simple type of clotting, and there was rapid diminution of chest movements, associated with

notable flattening. If the lung became atelectatic, bronchial breathing and pyrexia might lead to an erroneous diagnosis of pneumonia.

3. Hemothorax with clotting and low-grade infection. In this variety of hemothorax, the organisms were usually encased in fibrinous masses, and the bacteriologist required the clot as well as specimens of pleural fluid for satisfactory aerobic and anaerobic cultures.

Early in the war, it was the British practice to delay aspiration of hemothoraces from 36 to 48 hours, because of the fear of bleeding. Air replacement was also advocated. The latter practice was soon dropped, and it gradually became the routine to aspirate the chest promptly, particularly when surgery was not needed to repair the parietal wound or to control hemorrhage. This policy, according to Tudor Edwards (*49*), was based on the following objectives:

1. To relieve intrapleural pressure.
2. To eliminate blood, which is an excellent culture medium.
3. To prevent massive clotting.
4. To secure early reexpansion of the lung and thus limit the area of involvement if infection should occur.
5. To shorten the period of invalidism.

Whenever it was practical, the British preferred to perform all thoracenteses in a separate room fully equipped for the purpose and in the charge of a trained orderly. When this arrangement was possible, from 20 to 30 aspirations could be handled daily. The procedure was explained to the patient, who was told that it would cause him little pain or discomfort. The site of puncture was decided by the study of roentgenograms in two planes. It was a common error to go in too low. The fluid was examined routinely by smear and culture. Serial roentgenograms were taken during the postoperative period, and the necessity for subsequent aspiration was determined by staff conferences. Breathing exercises were part of the routine management.

The British, like U.S. Army surgeons, were somewhat slow to realize the importance of distinguishing between posttraumatic empyema, which gave rise to a far higher incidence of chronicity if not properly treated, and metapneumonic empyema. They explained the delay, as did U.S. surgeons, by the fact, already noted, that this difference was not emphasized as it should have been at the end of World War I, because the plethora of cases of influenzal empyema completely overshadowed the small number of cases of posttraumatic empyema.

By the end of 1943, the British had learned that clotted hemothorax was best handled by what they termed "turning out the clot," through a small intercostal incision. The chest wall was sutured at the conclusion of the operation, and the secondary effusion was aspirated regularly.

This technique, although it greatly reduced the risk of empyema, was not always followed by satisfactory reexpansion of the lung. Decortication,

which had been introduced by Major Burford of the 2d Auxiliary Surgical Group (p. 27), proved the answer to this problem and came into general use. The majority of surgeons considered that results were greatly improved by temporary intercostal drainage, especially when several tubes were used, with one or more in the apex of the pleural cavity. Other surgeons closed the chest and relied on aspiration and instillation of penicillin.

When decortication came into general use, results were secured far more promptly, and were far better, than the results achieved by rib resection and drainage. Casualties treated by the latter method usually required months of hospital treatment and, despite it, often went on to develop chronic empyema, which had to be managed by elaborate thoracoplastic procedures and which often resulted in permanent disability.

Tudor Edwards (*49*), in a presentation at the Inter-Allied Conference on War Medicine in January 1945, produced evidence of the improved results accomplished by early aspiration. In World War I, the British incidence of empyema had been 37 percent. In 249 chest injuries studied in 1943, the incidence of empyema had been 21.6 percent when aspiration was delayed beyond 48 hours and 12.5 percent when it had been done earlier. In 1,683 casualties treated in chest centers in the United Kingdom between D-day and 30 September 1944, after early aspiration had become routine, there were only 148 cases of empyema, 8.7 percent. There were only 9 deaths in these 1,683 chest injuries, 5 in the first 251 patients received in the chest centers and 4 in the remaining 1,432 patients. Penicillin, while invaluable in infected thoracic wounds, did not play a major role otherwise in the satisfactory results. What mattered most was that the pleural cavity be kept dry. If this was accomplished, infection did not gain a foothold.

GERMAN CHEST SURGERY IN WORLD WAR II

On 3 May 1945, an Allied Force Headquarters directive made captured German prisoners who were wounded or ill the responsibility of the Fifth U.S. Army medical service (*50, 51*). The following week after the final German surrender in Italy, the theater surgeon, Brig. Gen. (later Maj. Gen.) Joseph I. Martin, directed that a number of qualified U.S. Army medical officers, among them Lt. Col. (later Col.) Howard E. Snyder, MC, Consultant in Surgery to the Fifth U.S. Army surgeon, visit German medical installations and make a complete survey of them.

Administrative Considerations

Casualties with chest injuries, like other casualties with major wounds, were usually evacuated to the rear from the German medical installation (Hauptverbandplatz) that corresponded with the U.S. Army clearing station. In a more forward station (Truppenverbandplatz), which corresponded with

a U.S. Army battalion aid station, an occlusive dressing had been applied to an open chest wound and, if necessary, tracheotomy had been performed. Shock therapy had also been instituted (physiologic salt solution, external heat by electric heaters, Coramine (nikethamide) or Periston).

The German medical field manual listed the thoracic surgery to be performed at the Hauptverbandplatz as tracheotomy, closure of open chest wounds, and aspiration of the pericardium if cardiac tamponade was present. Blood and blood substitutes were also administered here.

Definitive primary surgery for patients with transportable chest wounds was performed at the Feldlazarett, which corresponded to a U.S. Army evacuation hospital. In very busy times, all casualties requiring major surgery might be evacuated to the general hospitals (Kriegslazaretten) assigned to an army group, to permit the units farther forward to care for men who would be able to return to their units within a reasonable time after operation. At such times, it was not unusual for patients with serious wounds to receive no surgery at all. The German system of medical care was extremely flexible, but its flexibility tended to favor the lightly wounded at the expense of the seriously wounded, the group to which U.S. Army medical officers gave first priority.

Clinical Considerations

Most of the patients with chest wounds whom Colonel Snyder observed in the German hospitals that he surveyed had been wounded weeks and months earlier. Their generally pale and anemic appearance was in contrast to the healthy appearance of most patients in U.S. Army hospitals. Clinical practices in the German medical service explained the difference: The Germans used blood in little more than homeopathic amounts, and their almost complete lack of aseptic techniques accounted for the prevalence of wound infection, the extent of which was many times more frequent than in U.S. Army hospitals and almost incomprehensible in the year 1945, regardless of military circumstances. About 60 percent of the chest patients had empyema, and Colonel Snyder was informed that this complication could be expected in about this proportion of shell-fragment wounds and in about 30 percent of all bullet wounds.

Opinions expressed by German surgeons concerning the management of chest injuries varied widely in details but were in general agreement in respect to most principles. The information secured was, in substance, as follows:

Shock of some degree was present with most chest wounds, and, unless there was a wide-open pneumothorax or a severe and menacing hemorrhage, its management took precedence. When there was serious internal bleeding or an increasing hemothorax, constant observation of the casualty was necessary, for shock might merge into collapse and the patient might bleed to death. When large numbers of wounded men were received at the same time and the surgeons were busy in the operating rooms, a junior medical officer, or whoever

else might be available, was appointed to make so-called collapse examinations, to be certain that a failing circulation and serious hemorrhage would be detected before they became irreversible.

Surgery was not performed in perforating thoracic wounds unless rib fragments had been indriven. The policy of early, repeated aspiration in hemothorax, which was routine in U.S. Army hospitals, was not employed in German hospitals, and there seemed no routine technique of management for this complication. Some surgeons said that aspiration was never employed unless it was required to relieve dyspnea associated with a large hemothorax or hemopneumothorax. Others said that aspiration was performed within the first 5 days after wounding. One consulting surgeon said that this had been the practice earlier in the war unless respiratory difficulties demanded immediate relief but that it had recently become the policy to employ aspiration as soon as the casualty recovered from shock, usually within 48 hours after wounding.

The treatment of empyema seemed rather more uniform. Closed intercostal (von Bülow) drainage was instituted as soon as infection or purulent exudation became evident. The catheter was attached to a water-seal bottle, which was usually converted into a Wangensteen-like suction apparatus by the use of two additional bottles. Drainage was continued until the cavity was obliterated. If this had not occurred at the end of 6 months after wounding, the empyema was considered chronic, and thoracoplasty and decortication were performed by a modified Schede technique. Rib resection was seldom used.

Only a small number of patients with thoracoabdominal wounds were observed in the German hospitals. None of the wounds were extensive, and in all instances, surgery had been limited to laparotomy with simple closure of the thoracic wall wound. No patients were encountered who had been treated by the transdiaphragmatic technique that was regarded so favorably by U.S. thoracic surgeons (vol. II, ch. III). When inquiries were made about this technique, the replies were vague. One surgeon stated that the thoracic approach might be used if the chest wound was large and the intra-abdominal wound small.

No facilities were provided for gas anesthesia or for positive pressure delivered by an anesthetic machine. A good machine was available for oxygen therapy, but it seemed to be seldom if ever used for expanding the lungs during intrathoracic surgery. No endotracheal tubes were seen, and no thoracic surgeon or anesthesiologist mentioned the endotracheal technique. Most anesthesia for chest surgery was supplemented by Pentothal sodium (thiopental sodium) given intravenously.

Since there were no facilities for positive pressure at operation and no well-trained anesthesiologist experienced in anesthesia for chest surgery, it was concluded that German casualties with chest wounds could not have had the advantages of modern intrathoracic and transdiaphragmatic surgical techniques.

SPECIAL TYPES OF WOUNDS

Thoracoabdominal Wounds

The British experience in the World Wars.—Thoracoabdominal wounds are discussed only briefly in the official British medical history of World War I. Gask (*12*), writing in 1919, noted that because of the protection afforded to the right side by the liver, the majority of these wounds were on the left side. He believed that the diaphragm could be repaired efficiently only from above. The preferred procedure was to open the chest, suture the diaphragm, deal with the chest injuries according to the indications, and then perform laparotomy if there was evidence of injury to hollow abdominal viscera. If a shell fragment had lodged in the substance of the liver, it might be necessary to remove the missile through the thoracotomy, excise any devitalized hepatic tissue, and then suture the diaphragm. Wounds which involved the diaphragm were apparently very troublesome; Lockwood and Nixon (*52*) considered their repair more important than the repair of any hollow or solid abdominal organ.

The discussion of thoracoabdominal wounds in the British history of World War II begins with the steadily improving prognosis of these injuries in World War I (*53*). In the Somme offensive in 1917, the recovery rate was 18.7 percent; all of the survivors had injuries of solid viscera only. In November 1917, General Bowlby reported to the Surgical Congress at Val-de-Grâce a recovery rate of 49 percent, and an almost similar rate was reported a few months later by Sir Cuthbert Wallace. The best results of the war, a recovery rate of 66.6 percent, were reported by Gordon-Taylor in the Hunterian Lecture in 1919, as the work of a group of Fourth British Army surgeons in the autumn of 1918. Maj. Charles Saint reported a recovery rate of more than 80 percent, but the experience included only 22 cases, in only 2 of which hollow viscera were involved. The situation was much the same in the 53 cases reported by Maj. John Anderson, in which the recovery rate was 79.2 percent.

Several series of thoracoabdominal injuries are mentioned in the official British medical history of World War II: 208 cases, with a case fatality rate of 38.0 percent; 59 cases, with a case fatality rate of 46 percent; a collected group of surgical cases, ranging in number from 10 to 78, in which the case fatality rate ranged from 8.3 percent in 12 cases (1 death) to 60 percent in 15 cases (9 deaths). The average case fatality rate was estimated at about 30 percent. As in the U.S. experience, the mortality rate depended upon the number of organs injured, whether the injured organs were solid or hollow, and the number and severity of the associated injuries. Emphasis was placed on the high incidence of thoracic complications likely after even promising surgery for thoracoabdominal wounds.

Associated hemothoraces required particularly careful attention because these patients were particularly prone to develop lower lobe atelectasis, massive pleural clotting, and empyema.

The popularity of the transthoracic approach was somewhat less among British than among U.S. surgeons, who found it increasingly useful as the war progressed. The explanation is probably that the British had relatively few thoracic surgeons assigned to their casualty clearing stations. A few British surgeons, after visiting forward U.S. medical installations, adopted the transthoracic approach and found it satisfactory. Even from the beginning of the war, of course, a surgeon with a thoracic bias would approach the thoracoabdominal wound from above if he were certain that the injuries were confined to the upper quadrants of the abdomen.

There was general agreement among British surgeons that the transthoracic approach was indicated:

1. In injuries of the spleen.
2. In right-sided thoracoabdominal wounds in which the only abdominal injury was in the liver. In such cases, repair of the diaphragm was impossible from below but simple from above.

If the thoracic wound was too high in the chest wall to permit free access to the diaphragmatic area, even after excision of the wound and traumatic thoracotomy, it was the British practice to deal with the wound of entry first and then carry out formal thoracotomy in the region of the eighth and ninth ribs. When a separate abdominal approach was employed, the wound of the chest was dealt with first.

The U.S. experience in World War I.—Thoracoabdominal wounds do not appear in the index of either the surgical volumes or the statistical volumes of the history of the U.S. Army Medical Department in World War I. Nevertheless, the seriousness of wounds involving the diaphragm was well recognized, as was the risk of bile leakage from an injured liver in right-sided thoracoabdominal wounds.

On the whole, there was fairly general agreement that when thoracoabdominal injury was suspected, it was best to attend to the chest injury first, partly because chest surgery was better tolerated than abdominal surgery and partly because more favorable conditions for laparotomy were thus established. If the chest wound was of the sucking type, it was mandatory to take care of it first. If it was small and if the major damage seemed to be in the abdomen, then the abdominal wound was handled first. In the chapter on abdominal injuries in the official U.S. history (*54*), Col. Burton J. Lee, MC, called attention to the straight vertical incision, beginning near the thoracic wound, used by the French Army surgeon, Pierre Duval. Repair of both the thoracic and the abdominal injury was possible through this incision.

In a report on thoracoabdominal injuries in 1920, Charles Gordon Heyd (*55*) pointed out that early in the war, all injuries of the diaphragm were repaired through the abdomen. It was only when chest surgery was established on a rational basis that repair through a thoracotomy approach was found to

be easier. It was also found possible, as the war progressed, to deal with certain intra-abdominal injuries through an enlargement of the diaphragmatic wound. Surgery through this approach was usually limited to the reduction of herniated viscera and the repair of injuries of the liver, the spleen, and portions of the cardiac end of the stomach. Injuries of the colon were also occasionally repaired through the diaphragm.

Heyd concluded that a critical review of the immense collective experience of World War I suggested that there should be a wider application of major thoracotomy to deal with wounds involving the diaphragm and the viscera immediately subjacent to it.

The Spanish Civil War experience.—Since Trueta's (*56*) book on the Spanish Civil War experience was written from the standpoint of soft-tissue wounds and fractures, thoracoabdominal wounds do not appear in the index. In Jolly's (*57*) text on the same experience, there is mention of 26 such wounds observed in 238 abdominal injuries (11 percent). There were 123 recoveries in the total series, 10 of which occurred in the 26 thoracoabdominal wounds. Not included in the series are a number of cases in which only the liver was injured and operation was not considered to be indicated because hemorrhage did not threaten life.

Jolly's impressions derived from his experience with these wounds in the Spanish Civil War were in substance as follows:

The operation selected should depend upon three considerations, (1) the type and direction of the wound; (2) the type of projectile; and (3) most important, the amount of damage to thoracic and abdominal viscera.

The transdiaphragmatic operation should be reserved for wounds in which there is (1) extensive damage to the chest, manifested by intrathoracic hemorrhage or open pneumothorax; (2) a large diaphragmatic perforation, with or without herniation; and (3) a wound of exit in the upper abdomen, indicating the course of the projectile. Transdiaphragmatic laparotomy is limited to the left side unless one considers suture or tamponade of the liver by a right-sided transpleural approach as a laparotomy.

The abdominal approach should be used in longitudinal wounds or wounds of considerable obliquity, in which it appears impossible to explore the abdominal cavity adequately by the transdiaphragmatic approach. Chest injuries are cared for first, and the diaphragm is repaired from above.

Both chest and abdominal cavities should be closed without drainage with the single exception of operations in which tamponade of the posterosuperior surface of the liver has been necessary. Even in such cases, an attempt should be made to convert the open pneumothorax into a closed wound. Suture of lacerations of the liver should be carried out when feasible. If tamponade is necessary, the wound track should be separated from the pleural cavity by high suture of the diaphragm to the parietal pleura above the chest wound.

RETAINED INTRATHORACIC FOREIGN BODIES

Early observations.—Many of the older reports of retained intrathoracic foreign bodies, like those of retained intracardiac foreign bodies, are of doubtful authenticity. A truly authentic case, however, was reported by Moore (*58*), in 1842. The wound, incurred in action at sea in 1796, was stuffed with clothing, some of which was coughed up 18 months later. The patient, a captain in the French merchant marine, continued on active duty for many years and had an exciting life. He participated in a number of active engagements, was twice captured by the enemy, and was once shipwrecked for 7 days. For the last 15 years of his life, his health was continuously poor. At autopsy, it was found that the shot, which was in the pulmonary substance on the right side, had entered between the fourth and fifth ribs, fracturing the fourth rib on the right. The diaphragm was at the level of the fifth rib, and the affected lung was a third of normal size.

As Collis and Qvist (*48*) expressed it, the tendency has always been to be "hypnotized" by the presence of large foreign bodies and to think immediate operation is essential. The early idea was to remove the objects whenever possible. Fraser (*4*), in his monograph on chest injuries in the Crimean War, told the story of the gallant officer, who, after being "poked at" for a long time by the surgeon, finally inquired about the point of the procedure. The surgeon said that he was searching for the bullet, and the wounded man replied, "I wish you had said so earlier, because you will find it in my waistcoat pocket."

Surveys of many series of cases in subsequent wars all indicate that while retained foreign bodies frequently, sooner or later, produce grave consequences, they may also continue completely asymptomatic. The difficulty is that there is no way of distinguishing one group of cases from the other.

The World War I experience.—No really reliable data on retained foreign bodies were collected during World War I. The chief controversy concerned the management of symptomless objects. There was general agreement that large objects (more than 2 cm. in any one dimension) should be removed, but there were sharp differences of opinion about smaller fragments or bullets in the absence of hemoptysis or of a clear inflammatory reaction about the object; in the latter circumstances, removal was recommended, regardless of size.

The British observed that rifle bullets and small pieces of shell lodged in the lung and pleural cavity seldom caused any disability and that, in the absence of infection, their presence did not delay the return of the soldier to full duty. Unless symptoms were present, therefore, they preferred to leave the objects in situ. In contradistinction to this general point of view, Grey Turner (*14*), in 1919, stated that after 4 years of military experience, he was more and more impressed by the fact that retained foreign bodies, no matter where they were situated, were likely to cause trouble.

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The psychosomatic aspects of retained foreign bodies played a part in their management from the Crimean War on (*4*). In the Civil War (*5*), it was found that "the peace of mind which the extraction of the foreign substance invariably induces in the patient is in itself a strong reason for using every judicious means for their removal." In World War I, Grey Turner (*14*) noted that patients received in home hospitals often complained of persistent shortness of breath and other irritative symptoms or simply suffered from the knowledge that they harbored foreign bodies. Even soldiers on pension, who did not have to fear return to military service, were apprehensive about them.

During World War I, a great deal of attention was paid to techniques of removing foreign bodies, including the blind fluoroscopic-triangulation technique of Petit de la Villeon and the use of the Hirtz compass.

The British experience in World War II.—Early in World War II, it was the British practice to remove foreign bodies from the lung routinely, even if they caused no symptoms (*13*, *48*). After 50 operations had been performed in one unit, removal of these objects was abandoned as unjustified unless it could be accomplished as part of thoracotomy performed on some other indication. As experience accumulated in air raids, the policy was developed of removing any fragment larger than 1 by 0.1 cm. Wedge resection of the lung, to include the foreign body, was the preferred technique, with the idea that damaged lung tissue should not be left in situ to become a source of future trouble.

Typical of the British military experience is d'Abreu's report of 339 retained missiles found in 1,000 thoracic wounds, of which 51 were in the mediastinal and cardiac tissues (*13*). Of the 221 objects in the lung, 100 were removed and 2 others could not be found; there were 2 deaths in the 102 operations. Of the 49 objects in the pleura, 44 were removed and 1 could not be found; there were no deaths.

Nicholson (cited by d'Abreu (*13*)), who reported 26 instances of empyema in 39 patients with retained intrapleural foreign bodies, had no doubt of the menace of subsequent infection and late hemoptysis in all such cases, though he granted that several years must elapse before the real risks could be proved. Most surgeons who advocated removal of foreign bodies on the ground of what might happen in the future agreed that there was no real urgency about operation.

WOUNDS OF THE HEART AND PERICARDIUM

The gravity of wounds of the heart has been recognized from ancient times. Aristotle's view that the heart alone, of all viscera, cannot withstand serious injury prevailed for many centuries.

It was not until 1895, according to Ramsdell's (*59*) excellent review in 1934, that the first attempt to suture a wound of the human heart was made, by Cappelan of Norway. He failed. In March of 1896, Farina of Italy

failed in a similar attempt. In the light of these failures, Stephen Paget's (*60*) remark, made shortly after Farina's attempt, seemed entirely justified: "Surgery of the heart," he said, "has probably reached the limits set by Nature to all surgery; no new method, and no new discovery, can overcome the natural difficulties that attend a wound of the heart."

The words had scarcely been uttered when they suffered the fate of many another medical generalization. In September 1896, Rehn of Frankfurt successfully sutured a stab wound of the right ventricle. In 1909, Peck collected from the literature 160 cardiac operations, 59 of which were successful. After successive additions to this collected series by Pool in 1912, Ballance in 1920, Smith in 1923, and Schoenfeld in 1927, Ramsdell, in 1934, tabulated 428 cardiac operations with 233 recoveries (55.5 percent). In the medical literature in the United States, 55 of these cases were recorded, in which there were 39 recoveries (70.8 percent). It is a pity that Ballance's (*61*) suggestion in the Bradshaw Lecture in 1920 has not been followed, that suture statistics be made up on the basis of whether or not the heart was opened at operation. In his collection of 150 surgical cases, in which the case fatality rate was 31.57 percent, 63 wounds were combat incurred; there were 16 deaths (26.03 percent).

The World War I experience.—Wounds of the heart do not appear in the index of the statistical volume of the history of the U.S. Army Medical Department in World War I, and they are dismissed briefly in the text of the surgical volume (*7*): Early operations on the heart and pericardium were infrequent because the wounds were either promptly fatal or were treated expectantly. Cardiac wounds disclosed by operation were "easily remedied, requiring little more than simple suture." The approach to wounds of such gravity is surprisingly casual.

A number of successful operations for cardiac wounds were done in the latter part of World War I by French surgeons, chiefly Pierre Duval. When there has been no confirmation by post mortem or exploration, however, it is often difficult to accept all recorded cases of cardiac wounds as authentic, and even exploration may not furnish absolute proof. D'Abreu (*13*), in his account of war wounds of the chest in World War II, questioned whether any of the four cases of early removal of a metal fragment from the heart recorded by Makins in the British official history of World War I (*62*) was "indubitably extracted from one of the heart chambers" except the missile removed by Fraser. At any rate, this patient recovered, as did Sampson's patient, who was operated on for a wound of the left ventricle. In the other two cases recorded by Makins, both instances of bullets in the cardiac wall, death followed surgery.

As d'Abreu observed, inspection of specimens in war museums attests the gravity of all wounds of the heart, whether they are caused by high-velocity missiles, shell fragments, or spicules of bone. Makins commented in the British medical history of World War I that the War Office Collection of specimens illustrated every lesion described from accumulated experience of

the whole history of surgery but contributed little or nothing not already gleaned from the classical literature of cardiac surgery. The magnificent British War Office Collection of specimens in the Royal College of Surgeons was largely destroyed by enemy action in May 1941, but, fortunately, drawings exist of most of them.

According to Makins (*62*), wounds of the heart involve the right ventricle, the left ventricle, the right auricle, and the left auricle in the descending order of frequency. In his opinion, the anatomic incidence corresponds with the relative degree of exposure of the cardiac surfaces toward the front of the body, plus the relative size of the area presented by the external aspect of each chamber. The published records, as well as the specimens in the War Office Collection, substantiated the great frequency of ventricular wounds and suggested that, in many instances, both ventricles were implicated. A possibly misleading feature of the War Office Collection, Makins noted, was that, with four exceptions, all the specimens were secured from patients who survived their wounds long enough to reach the hospital. Limited as was the British experience in World War I, he concluded, it showed that "rare" conditions were more frequent than previously supposed, and it also afforded evidence "that the treatment of injuries to the heart has now become a definite and promising field for the surgeon."

Cardiac surgery between the World Wars.—Wounds of the heart do not appear in the indexes of either Trueta's (*56*) or Jolly's (*57*) books on the Spanish Civil War. Between the World Wars, however, the writings of Tuffier, Duval, Carrel, Graham, Beck, Cutler, Bigger, Elkin, and others recorded successive advances in cardiac surgery. During this period, the basic techniques were developed that were used so successfully for the management of these wounds in World War II. Elkin's (*63*) cumulative study of 61 cases from Emory University Division of Grady Hospital, Atlanta, Ga., published in 1944, may be taken as typical of the status of civilian traumatic cardiac surgery at the time the United States entered World War II. In the first 38 patients, all treated before 1940, there were 16 deaths (42 percent). Seven of the fatalities were caused by infection. In the 23 patients treated after this date there were 5 deaths (22 percent), none of which was caused by infection. The lowered case fatality rate and the absence of fatal infection could not be attributed to chemotherapy; penicillin was not yet available, and the sulfonamides were used in only one case in the series. The improved results were attributed, instead, to more careful surgical technique and more precise preoperative preparation, particularly the use of intravenous replacement therapy.

The British experience in World War II.—The British experience with wounds of the heart in World War II does not seem to have been extensive; these injuries do not appear in the index of the surgical volume of the official history. D'Abreu (*13*), in the supplement on chest surgery in the *British Journal of Surgery*, described several small ventricular wounds treated by suture but devoted his chief attention to retained foreign bodies. He mentioned 4 or 5 isolated cases in which they were removed and also reported 51

cases, out of 339 cases of retained missiles, in which foreign bodies were retained in the mediastinal and cardiac tissues. Operation was undertaken in 30 cases, and the objects were successfully removed in 28. There were two deaths. One patient died on the operating table after an uneventful operation, and the other in 24 hours, "with the heart in fibrillation." In the latter case, the object, which lay in the wall of the left ventricle, had not been removed because of the friability of the heart muscle. Two of the missiles removed were in contact with the thoracic aorta, and another was removed from the lumen of the subclavian vein, which was sutured without subsequent edema.

Retained foreign bodies.—The first operation for a foreign body in the heart seems to have been performed by Gerard in 1834. Between 1900 and 1938, according to Decker's (*64*) 1939 review of the literature, 109 cases were recorded. In nine instances the object passed out of the heart and into the arterial circulation. In the remaining 100 cases, there were 8 deaths in the 47 patients treated surgically and 16 in the 53 patients treated conservatively. The authenticity of case reports in which neither operation nor autopsy was performed is sometimes open to doubt, as just mentioned, and there were the usual arguments as to what harm was likely if retained objects were left in situ. Delorme cited the history of a veteran of the Napoleonic Wars who lived for 52 years with a round bullet fixed by adhesions in the pericardial sac and whose only complaint was that he could not lie on his left side, but the sequence of events was often much more serious.

Migrating missiles, said d'Abreu (*13*), were followed in "marathon pursuit" as they moved from body cavity to body cavity. He continued:

> During the 1914–19 and 1939–45 conflicts, the existence of a fragment of metal in the heart wall or within one of the cardiac chambers seemed to provide an irresistible challenge to surgical courage and enterprise. The swirlings and gyrations of bullets and fragments of high explosive were watched by radiologist and surgeons with the same interest that "astronomical observers bestow on minor planets," and these fluoroscopic séances only served to whet the avidity of operators to rid the owners of their unpleasant tenants.

Blast Injuries

Blast injuries, a form of chest injuries which occur from exposure to the detonation of some high explosive, were not described as such in World War I. Their characteristic manifestations, however, were recognized. There were a number of references to the finding of dead soldiers on the battlefield, after explosions, without any external injury or any serious external injury, often with the nose and mouth full of bloodstained fluid. Thomson (*65*) found 24 such cases in 250 chest wounds. This incidence is close to the 10-percent incidence reported in the U.S. Medical Department history of the First World War (*7*). In this history, these injuries are described as involving the viscera alone and as due to indirect violence or sudden and considerable changes in atmospheric pressure resulting from nearby explosions.

Blast injuries were also reported in the Spanish Civil War. Perhaps for that reason, but more likely because of the injuries caused by indiscriminate

bombing early in World War II, there was a considerable outpouring of interest, as manifested by numerous special reports and experimental studies in the literature (*66*), (vol. II, ch. I). As a matter of fact, at least in land warfare, blast injuries proved an almost inconsequential cause of injury and death among U.S. troops.

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CHAPTER II

General Considerations of Thoracic Wounds

Frank B. Berry, M.D.

CLASSIFICATION OF CHEST WOUNDS

Wounds of the thorax are divided basically into two groups, (1) nonpenetrating wounds of the chest wall, and (2) intrathoracic wounds, which may be either penetrating or perforating. In a penetrating intrathoracic wound, the wounding agent has penetrated into the pleura, and there is no wound of exit. In a perforating wound, the missile has completely traversed a segment of the pleural cavity.

Statistics prepared by the Medical Statistics Division, Office of The Surgeon General, Department of the Army, bear out the clinical impression that penetrating wounds of the chest were several times more frequent in World War II than perforating wounds (table 2).

It was generally agreed by those with experience in the reparative phase of management of thoracic wounds that the perforating type of injury was less likely to be associated with complications than the penetrating type:

1. In the perforating type of wound, there were no retained foreign bodies to invite infection, and the likelihood of immediate threatening symptoms because of gravely disturbed physiology was far less.
2. There was less tissue destruction in bullet wounds, which accounted for a much higher proportion of perforating wounds than did shell fragments.

CHARACTERISTICS OF CHEST WOUNDS

Even chest surgeons with a wide experience in civilian practice had had little or no experience with the type of chest wounds encountered in World War II unless they had also served in World War I, and the number in this category was very small.

The chest injuries with which medical officers had dealt in their pre-Army experience were most often stab wounds or low-velocity bullet wounds of the closed, penetrating type, in which extensive tissue damage, serious cardiovascular disturbances, and infectious sequelae, while they might occur, were not the rule except for the neglected hemothorax, with the resulting fibrothorax. In the 1,187 chest injuries reported by Boland (*1*) from the Emory University Division, Grady Hospital, Atlanta, Ga., in 1936, empyema and other serious infections occurred in less than 2 percent of all cases. In the 553 cases reported by Elkin (*2*) from the Emory University Division, Grady Hospital, for the

TABLE 2.—*Number of admissions for battle injuries and wounds of the thorax and thoracoabdominal region in the U.S. Army, by anatomic site and nature of injury, 1944* [1]

[Preliminary data based on tabulations of individual medical records]

Anatomic site	All injuries and wounds	Fractures: Total	Fractures: Simple	Fractures: Compound: Total	Fractures: Compound: Comminuted	Fractures: Compound: Other	Traumatic amputations, avulsions, etc.	Wounds: Penetrating	Wounds: Perforating	Wounds: Lacerated	Wounds: Abraded or contused	Wounds: Unqualified	Crushing	Burns	Other traumatisms
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Thorax:															
Thorax, generally	10, 221	3	1	2	2		6	4, 859	1, 215	524	791	391	23	32	2, 377
Thoracic wall, generally	4, 538	4		4	4		3	2, 952	579	439	326	122	2	3	108
Posterior thoracic wall	2, 931						1	2, 076	316	272	129	63		4	70
Axilla	1, 152							683	254	134	30	41		3	7
Ribs	1, 852	1,745	381	1,364	1, 064	300	1	34	10	2	37	3			20
Heart:															
Heart, generally	15							5	1	1	1	3			4
Auricle, left	6							1	3	2					
Auricle, right	11							5	2	2					2
Ventricle, left	13							8	1	1		1			2
Ventricle, right	20							13				1			6
Pericardium	32							18	5	7					2
Myocardium	6							3	1	1					1
Heart, other	1							1							1
Total heart	[2](105)							[2](54)	[2](13)	[2](14)	[2](1)	[2](5)			[2](18)

Lungs	3, 068	-----	-----	-----	-----	-----	1	1, 516	492	585	72	25	-----	-----	377
Trachea	67	1	1	-----	-----	-----	2	24	25	11	-----	1	-----	-----	3
Bronchi	3	-----	-----	-----	-----	-----	-----	1	-----	1	-----	-----	-----	-----	1
Mediastinum	37	-----	-----	-----	-----	-----	-----	31	4	-----	-----	-----	-----	-----	2
Pleura	144	-----	-----	-----	-----	-----	3	70	33	34	1	-----	-----	-----	3
Thoracic duct	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Esophagus	16	-----	-----	-----	-----	-----	-----	2	11	1	-----	-----	-----	1	1
Diaphragm	48	-----	-----	-----	-----	-----	1	10	20	13	-----	-----	-----	-----	4
Thorax, other	882	73	14	59	44	15	4	464	102	95	60	24	-----	1	59
Total	25, 064	1,826	397	1,429	1, 114	315	22	12, 776	3, 074	2, 125	1, 447	675	25	44	3, 050
Thoracoabdominal region	1, 752	1	-----	1	1	-----	-----	1, 047	594	38	7	41	1	-----	23

[1] Excludes cases carded for record only.
[2] Figures in parentheses are subtotals.

same year, the rate of infection was 1.4 percent. The same proportion of infections occurred in the 2,091 chest injuries collected by DeBakey (*3*) from Charity Hospital of Louisiana at New Orleans for the 5-year period ending in 1936, and hemothorax was a factor in only 13.8 percent of the cases.

In combat-incurred wounds of the chest in World War II, this situation was reversed. Tissue and structural damage was extensive and serious because the majority of injuries were caused by shell fragments. Hemothorax occurred in 75 percent or more of all cases. Finally, although infectious complications were far less frequent than in World War I, they were still more frequent than in civilian practice.

WOUNDING AGENTS

Incidence.—The tendency to employ wounding agents with greater destructive ability in successive wars is evident from the figures. In the American Civil War, approximately 9 of every 10 wounds were caused by low-velocity bullets and only 1 by high explosive shell fragments (*4*). In later wars, this ratio was reversed. In World War I, approximately 7 of every 10 wounds were caused by high explosive shells (*5*). In World War II, the ratio was about eight wounds caused by shell fragments to every two caused by bullets. The implications as to the increased severity and destructiveness of the resulting wounds are clear.

The same situation occurred in chest wounds as in other wounds. In the Civil War, only 12.5 percent of all wounds of the thorax were caused by high explosives. In 1944, the year in which the majority of U.S. Army wounds were sustained, only 5,502 of the 25,064 admissions[1] for chest wounds were reportedly caused by bullets from rifles, machineguns, and other similar weapons (table 3). A like proportion was maintained for the entire war (table 4).

Case fatality rates.—There was a striking difference in both World Wars in the case fatality rates of bullet wounds and wounds resulting from high explosive shells. In World War I, among 20,662 wounds in U.S. troops caused by rifle and pistol bullets and involving all areas of the body, the case fatality rate was 4.7 percent, compared to a rate of 7.2 percent in 52,106 wounds caused by shell fragments. The respective case fatality rates in wounds of the chest were 31.9 percent and 46.6 percent (*5*, *6*).

Similar differences in the case fatality rate were evident in World War II, as is shown in tables 5 and 6. In 1944, for instance, 663 of the 2,010 deaths occurred in 5,502 wounds caused by bullets, while 1,120 occurred in the 16,841 wounds produced by exploding shells, tables 3 and 5.

[1] The Medical Statistics Division, Office of The Surgeon General, Department of the Army, defines wound admissions as instances in which a wound was reported as the primary cause for the patient's being hospitalized for medical treatment or otherwise treated in an excused-from-duty status. In the tables used in this chapter and prepared by this Division, such variables as the causative agent, the nature of the traumatism, and its anatomic location pertain to the admission diagnosis.

TABLE 3.—*Number of admissions*[1] *for battle injuries and wounds of the thorax in the U.S. Army in 1944, by causative agent and theater*[2]

[Preliminary data based on tabulations of individual medical records]

Causative agent	Outside continental United States[3]	Europe	Mediterranean	China-Burma-India	Southwest Pacific	Central and South Pacific
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
Bomb and bomb fragments	544	315	110	2	107	10
Shell, shell fragments, and flak	16, 841	12, 494	3, 515	61	493	274
Bullet, machinegun, rifle, etc	5, 502	3, 914	681	58	584	262
Landmine, boobytrap	518	329	163	2	13	11
Grenade and grenade fragments	478	261	91	9	69	48
Explosion of ammunition, weapons, etc	107	59	30	------	10	8
War gases, screening smoke, incendiaries	23	17	1	1	1	3
Firearms, mechanism or effects of discharge of	47	41	4	------	2	------
Aircraft, excluding aircraft weapons	155	100	21	6	21	7
Parachute jump	60	42	11	2	5	------
Boat sinking and accident	49	33	7	------	4	3
Tank, tractor, caisson	40	32	7	------	1	------
Motor vehicle, passenger and cargo	64	54	9	------	------	1
Vehicle, other and unspecified	16	12	4	------	------	------
Cutting or piercing instruments	31	18	------	1	10	2
Fire, hot liquid, or objects	9	5	2	------	1	1
Fall or jump, twisting, turning, lifting, slipping, etc	220	131	66	1	17	5
Other and unspecified	360	240	61	2	40	17
Total	25, 064	18, 097	4, 783	145	1, 378	652

[1] Excludes cases carded for record only.

[2] There were no records of admissions for injuries or wounds of the thorax during 1944 in the Middle East, North America, or Latin America.

[3] Includes 9 admissions aboard transports.

Characteristics of bullet and shell-fragment wounds.—The different characteristics of the two types of wounds offer some explanation of the different mortality rates. Bullet wounds have the following general characteristics:

1. They are likely to be sharply localized penetrating wounds or simple through-and-through wounds, with a small puncture point of entry and a somewhat larger exit. This is especially true of wounds produced by bullets from small-caliber arms. When the wound is simply penetrating, the bullet obviously has lost most of its velocity. For example, there is the penetrating wound caused by a bullet in the suprasternal notch, in which the bullet had penetrated only the skin, without any damage to the deeper structures.

2. In bullet wounds, tissue contamination and structural damage are likely to be limited and localized. The amount of the damage depends entirely upon the velocity already expended by the bullet. If the bullet is still truly

TABLE 4.—*Number of admissions* [1] *for battle injuries and wounds of the thorax* [2] *in the U.S. Army, by causative agent and year, 1942–45* [3]

[Preliminary data based on tabulations of individual medical records]

Causative agent	1942–45	1942	1943	1944	1945
	Number	*Number*	*Number*	*Number*	*Number*
Bomb and bomb fragments	873	37	114	544	178
Shell, shell fragments, and flak	27, 591	111	1, 645	16, 841	8, 994
Bullet, machinegun, rifle, etc	10, 608	140	545	5, 502	4, 421
Landmine, boobytrap	1, 037	1	123	518	395
Grenade and grenade fragments	987	3	33	478	473
Explosion of ammunition, weapons, etc	262	5	78	107	72
War gases, screening smoke, incendiaries	39			23	16
Firearms, mechanism or effects of discharge of	115	1	7	47	60
Aircraft, excluding aircraft weapons	252	3	37	155	57
Parachute jump	102	1	18	60	23
Boat sinking and accident	75	2	17	49	7
Tank, tractor, caisson	78	2	7	40	29
Motor vehicle, passenger and cargo	115		13	64	38
Vehicle, other and unspecified	31		2	16	13
Cutting or piercing instruments	81	1	11	31	38
Fire, hot liquid, or objects	17		1	9	7
Fall or jump, twisting, turning, lifting, slipping, etc	480		31	220	229
Other and unspecified	683	21	109	360	193
Total	43, 426	328	2, 791	25, 064	15, 243

[1] Excludes cases carded for record only.
[2] Excludes thoracoabdominal region.
[3] Includes admissions in December 1941. Excludes cases wounded or injured in action in the Philippine Islands in 1941 and 1942.

in the high-velocity range, it causes the usual explosive damage to the tissues along its path. Because of the differences between tissue and muscle and bone, this damage, of course, varies, and is less for lung tissue. This is well described in the volume on wound ballistics (7).

3. The track of a bullet is long and narrow and is marked by coagulation and searing of the tissues through which the missile passes, together with more or less distant tissue damage depending upon velocity.

4. Cardiorespiratory disturbances occur less frequently in bullet wounds than in the larger wounds so commonly caused by shell fragments. Because of the perforating character of the wound, the wounds of entrance and exit tend to be relatively sealed, so that, barring extensive hemorrhage within the chest, or damage to a larger bronchus with the resulting rapid accumulation of hemothorax or tension pneumothorax, there is less physiologic disturbance.

TABLE 5.—*Number of deaths*[1] *among admissions in 1944 for battle injuries and wounds of the thorax in the U.S. Army, by causative agent and theater of admission*[2]

Causative agent	Outside continental United States[3]	Europe	Mediterranean	China-Burma-India	Southwest Pacific	Central and South Pacific
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
Bomb and bomb fragments	40	21	14	------	5	------
Shell, shell fragments, and flak	1, 120	840	231	2	32	15
Bullet, machinegun, rifle, etc	663	457	61	7	92	45
Landmine, boobytrap	41	26	12	------	3	------
Grenade and grenade fragments	10	4	4	------	1	1
Explosion of ammunition, weapons, etc	3	1	1	------	1	------
Firearms, mechanism or effects of discharge of	1	1	------	------	------	------
Aircraft, excluding aircraft weapons	6	3	1	1	1	------
Tank, tractor, caisson	3	2	------	------	1	------
Vehicle, other and unspecified	2	--------	2	------	------	------
Cutting or piercing instruments	2	1	------	------	1	------
Other and unspecified	119	95	13	------	7	4
Total	2, 010	1, 451	339	10	144	65

[1] Consists of all admissions which ended in death, not necessarily due to the injury or wound causing admission or necessarily occurring during the year of admission.
[2] There were no records of admissions for injuries or wounds of the thorax during 1944 in the Middle East, North America, or Latin America.
[3] Includes 1 death among admissions aboard transports.

Bullet wounds have also certain unfavorable characteristics:

1. Bullets that strike the thoracic cage tangentially or emerge from the chest in an erratic course sometimes produce larger defects in the chest wall than normally expected.

2. Bullets can cause considerable contusion of the structures through which they pass, or, in the case of a high velocity, very superficial wound of the chest wall, which is almost of a searing nature, they might indeed cause a complete reflex temporary dysfunction of the hemithorax, with resulting atelectasis of the underlying lung. The writer personally has seen two such instances.

3. Bullets often traverse greater distances than shell fragments, and their tendency to involve more than one body cavity is conspicuous.

Fragments of high explosive shells, bombs, and mines have the following characteristics:

1. They are likely to produce great destruction of tissue because of their irregular shape, frequently large size, and high spin.

2. When a shell fragment is the causative missile, the wound in the chest wall is likely to be larger, open injuries more frequent, and multiple injuries also more frequent than when a bullet is the wounding agent.

TABLE 6.—*Number of admissions and case fatality ratios for battle injuries and wounds of the thorax* [1] *in the U.S. Army, by causative agent, 1942–45*

[Preliminary data based on tabulations of individual medical records]

Causative agent	Admissions [2]	Admissions resulting in death [3]	Case fatality ratio
	Number	*Number*	*Percent*
Bomb and bomb fragments	873	67	7.7
Shell, shell fragments, and flak	27, 591	1, 880	6.8
Bullet, machinegun, rifle, etc	10, 608	1, 316	12.4
Landmine, boobytrap	1, 037	100	9.6
Grenade and grenade fragments	987	26	2.6
Explosion of ammunition, weapons, etc	262	7	2.7
War gases, screening smoke, incendiaries	39	------	------
Firearms, mechanism or effects of discharge of	115	1	.9
Aircraft, excluding aircraft weapons	252	10	4.0
Parachute jump	102	------	------
Boat sinking and accident	75	------	------
Tank, tractor, caisson	78	3	3.8
Motor vehicle, passenger and cargo	115	1	.9
Vehicle, other and unspecified	31	2	6.5
Cutting or piercing instruments	81	4	4.9
Fire, hot liquid, or objects	17	------	------
Fall or jump, twisting, turning, lifting, slipping, etc	480	1	.2
Other and unspecified	683	195	28.6
Total	43, 426	3, 613	8.3

[1] Excludes thoracoabdominal region.

[2] Excludes cases carded for record only. Includes admissions in December 1941. Excludes cases wounded or injured in action in the Philippine Islands in 1941 and 1942.

[3] Consists of all admissions which ended in death, not necessarily due to the injury or wound causing admission or necessarily occurring during the year of admission.

3. As a consequence, hemorrhage, shock, and cardiorespiratory disturbances are more frequent and severe because of the sharply deranged cardiorespiratory physiology.

4. Shell fragments carry into the tissues with them fragments of bone, bits of clothing, and other foreign contaminants. Because of the resulting contamination, the incidence of infection is therefore higher than in wounds caused by bullets.

5. High explosive shell fragments are retained much oftener than bullets. Nicholson's and Scadding's (*8*) figures are typical. In an analysis of 291 penetrating wounds of the chest treated in British forward installations in the Middle East, they found retained foreign bodies in 91 percent of such wounds but in only 32 percent of the wounds caused by bullets.

6. For these various reasons, open operative intervention is necessary more often in shell-fragment wounds than in bullet wounds. The wounds are frequently difficult to manage, and both morbidity and mortality rates are somewhat higher.

VELOCITY OF MISSILES

A careful distinction must be made between high-velocity and low-velocity missiles. The fragments of a shell containing high explosives have an extremely high velocity immediately following the explosion, but this initial velocity is subject to a very rapid decay and so, as a rule, when the missiles strike, they have lost much of their original speed and are well within the low-velocity range. The modern bullet in its effective trajectory range is almost always a high-velocity agent. Two bullets from an automatic weapon that strike the chest in close proximity to each other, for example, are likely to produce much greater damage than the sum of the two injuries if the hits are farther apart.

While the disruptive effect of high-velocity missiles on tissues is far greater than that of low-velocity missiles, it is also proportional (1) to the density of the tissues affected and (2) to whether secondary missiles consisting of bone fragments are developed. Structures of lesser density sustain appreciably less damage than structures of higher density. In this respect, the lung, which is the least dense of all body structures and which, in its totally expanded state, is of little greater density than the atmosphere, is unique. High-velocity missiles that traverse the pulmonary tissue therefore often cause surprisingly little pulmonary damage. The high immediate lethality of high-velocity wounds of the chest is apparently directly related to the percentage chance of damage to vital structures, particularly the heart and great vessels. If the high-velocity missile does not inflict a mortal wound, then it often traverses the chest with considerably less damage to the thoracic contents than is caused by a low-velocity shell fragment.

The type of missile and its inherent velocity are thus the chief determinants of the type of thoracic wound produced. Other determinants include the size and course of the missile (p. 55), the distance of the casualty from its point of origin, and his position when he was wounded (p. 230).

VULNERABILITY OF THE CHEST TO WOUNDING

Definition of chest wounds.—It is regrettable that up to this time there has been no agreement as to exactly what portion of the body constitutes the chest. Without a generally accepted definition, there has naturally been disagreement in the statistics for chest wounds.

Beebe and DeBakey (*9*) quoted Churchill's demarcation of the surface areas of the body, in which he defines the chest as follows:

> * * * On the surface * * * the simplest line is one that approximately follows the lower limits of the pleural cavities. In front, this line passes from the lower end of the sternum obliquely downward along the costal margin to the 8th intercostal space. A horizontal line carried around the body to meet the corresponding point on the other side will pass approximately over the midpoint of the 11th rib and the spine of the first lumbar vertebra. The chest region as described includes the entire circumference of the trunk and is not interrupted posteriorly by a "back" or a "spine".

Earlier wars.—It is unfortunate that this, or some other, anatomic specification has never come into general use. On the other hand, however the chest may be defined and delimited, it presents a large target area, and it is therefore logical to expect that it would sustain a correspondingly large number of battle wounds. Since it houses vital structures of the first order, it might also be logically expected that these wounds would be followed by a large number of deaths.

In addition to the size of the target which the various areas of the body present, their exposure varies with the special types and circumstances of combat, as well as with the relative degree of protection afforded by the position of the body, the clothing worn, the terrain, the availability of foxholes and trenches, and similar considerations. Any or all of these factors may account for the differences between the actual and expected distribution of body injury.

Modern offensive weapons have a much greater wounding potential, with correspondingly greater lethality, than older weapons. In spite of this, the incidence of combat-incurred injuries of the chest has remained substantially the same in successive wars of the past 100 years (p. 5). It seems reasonable to assume, therefore, that the most important single factor controlling the incidence of chest wounds is, as in all other wounds, the factor of body area exposed. The exhaustive study of wound ballistics made by Col. Ashley W. Oughterson, MC, in the Southwest Pacific Area (*10*) makes this clear. He and his associates could not accept the aiming of missiles as an explanation of the location of hits.

INCIDENCE AND CASE FATALITY RATES

Hoche's (*11*) extensive studies of 11,000,000 war wounds in English, French, American, and German casualties in World War I showed that 6 percent were wounds of the chest. Only wounds of the limbs, head, face, and neck exceeded wounds of the chest in frequency. The total case fatality rate was 8 percent. The rate for wounds of the chest was 56 percent, this being second only to the case fatality rate of 68 percent in abdominal wounds. In a special study of 12,350 fatalities, Hoche found that wounds of the chest seemed to be the primary cause for 20 percent of all deaths, in comparison with 11.8 percent for wounds of the abdomen and pelvis, 47 percent for wounds of the head, and 9.9 percent for wounds of the limbs.

Official figures for the U.S. Army in World War I show 174,296 admissions for all battle injuries exclusive of gas injuries (*5*). Of these wounds, 4,595 (2.6 percent) involved the chest. The case fatality rate for all wounds was 7.73 percent and for chest wounds 24.05 percent.

Attention has been called elsewhere (p. 7) to the incredibly low incidence of both British and U.S. chest injuries recorded in World War I and to the possible explanation, that some wounds of the thorax in the U.S. records are hidden in wounds of the back or the shoulder area, which are listed separately.

With these exceptions, the incidence of chest wounds in all recorded wars has been close to 8 percent.

World War II.—Official figures for U.S. Army casualties in World War II show that in a total of 599,788 battle wounds and injuries (table 7), 20,810 were fatal (table 8). Of the total wounds and injuries, 43,426 (7.24 percent) were wounds of the chest (table 9), of which 3,613 (8.3 percent) were fatal (table 10). These figures cover all casualties who survived to be hospitalized but do not cover those who died on the battlefield or in battalion aid stations or collecting or clearing stations. Not all of the 3,613 fatalities were necessarily due to wounds of the chest, but every casualty who died had such a wound.

Statistics for the Tunisian campaign in 1942–43 are not satisfactory, but as far as can be estimated from them, not more than 6 or 7 percent of the casualties who reached forward evacuation hospitals, corps clearing stations (in which surgery was then done), and the single surgical hospital operating in the area had wounds of the chest. In contrast, of approximately 50,000 casualties treated in Fifth U.S. Army hospitals in 1944, about 9 percent of the 46,000 hospitalized in evacuation hospitals had wounds of the chest (*12*). The remaining 4,000 casualties, practically all of them seriously wounded and nontransportable, were treated in field hospitals; 25 percent had thoracic wounds.

As these figures indicate, there was a remarkable increase during the course of the war in the number of casualties who survived to reach a hospital. One undoubted reason for the improvement, as well as for the improvement in case fatality rates, was the development and utilization of field hospitals, staffed with auxiliary surgical group teams, close to the frontline (p. 92).

It was naturally to be expected that the farther forward casualties with thoracic wounds were treated, and the larger the number of seriously wounded casualties treated, the higher would be the case fatality rates. In 4,320 chest injuries, for instance, in Seventh U.S. Army hospitals, the total case fatality rate was 5.4 percent, but it was 8.7 percent in field hospitals as compared with 3.3 percent in evacuation hospitals.

In an analysis of 22,246 admissions to Fifth U.S. Army hospitals between 1 August 1944 and 31 May 1945, Lt. Col. (later Col.) Howard E. Snyder, MC, Consultant in Surgery, Fifth U.S. Army, and Capt. (later Maj.) James W. Culbertson, MC (*13*), found that intrathoracic and thoracoabdominal wounds accounted for 6.29 percent of all admissions and 28.2 percent of all deaths over this special period. In an analysis of 1,450 deaths in Fifth U.S. Army hospitals, including 39 cases in which the casualties were dead on arrival, these same observers found that 212 of the deaths were the result of thoracoabdominal wounds and 138 the result of intrathoracic wounds. The combined proportion of deaths (24.1 percent) was exceeded only by the deaths in intra-abdominal wounds (28.1 percent, 408 fatalities).

In spite of the increase in the lethal potential of modern weapons of war, there was an encouraging reduction in the case fatality rate for chest wounds as

TABLE 7.—*Number of admissions*[1] *for battle injuries and wounds in the U.S. Army, by nature of traumatism and theater of admission, 1942–45*[2]

[Preliminary data based on tabulations of individual medical records]

Nature of traumatism	Outside continental[3] United States	Europe	Mediterranean	Middle East	China-Burma-India	Southwest Pacific	Central and South Pacific	North America	Latin America
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
All battle injuries and wounds	599, 788	393, 992	107, 326	315	2, 616	59, 651	33, 605	1, 512	36
Fractures:									
Simple	16, 194	9, 765	3, 681	38	129	1, 527	932	65	2
Compound	114, 568	79, 259	18, 206	45	451	10, 350	5, 944	271	5
Comminuted	100, 023	70, 605	15, 124	33	322	8, 715	4, 971	223	4
Other	14, 545	8, 654	3, 082	12	129	1, 635	973	48	1
Total fractures	130, 762	89, 024	21, 887	83	580	11, 877	6, 876	336	7
Traumatic amputations, avulsions, etc	12, 900	8, 744	2, 278	4	38	1, 160	661	10	---
Wounds, penetrating	194, 538	128, 099	37, 802	101	747	17, 691	9, 657	338	13
Wounds, perforating	64, 933	43, 249	9, 612	11	317	7, 751	3, 707	264	5
Wounds, lacerated	57, 522	37, 133	10, 187	26	286	6, 390	3, 350	102	5
Wounds, abraded or contused	28, 098	17, 594	6, 686	17	126	2, 361	1, 217	26	---
Wounds, unqualified	19, 024	6, 599	3, 759	31	129	3, 995	4, 363	94	2
Crushing	208	99	55	2	5	30	17	---	---
Burns	5, 906	3, 197	943	7	59	1, 070	570	1	1
Other traumatisms	85, 897	60, 254	14, 117	33	329	7, 326	3, 187	341	3

[1] Excludes cases carded for record only.
[2] Includes 439 admissions in December 1941 in the Pacific. Excludes 1,231 cases wounded or injured in action (TAGO source) in the Philippine Islands in 1941 and 1942.
[3] Includes 735 admissions aboard transports.

TABLE 8.—*Number of U.S. Army personnel who died of battle injuries and wounds* [1] *during 1942–45,* [2] *by nature of traumatism and theater of admission*

[Preliminary data based on tabulations of individual medical records]

Underlying cause of death	Outside continental United States [3]	Europe	Mediterranean	Middle East	China-Burma-India	Southwest Pacific	Central and South Pacific	North America
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
All injuries	20, 810	12, 521	3, 733	11	127	2, 936	1, 431	30
Fractures:								
Simple	359	140	118	------	5	59	32	2
Compound	3, 313	2, 229	549	2	16	334	174	6
Comminuted	2, 290	1, 605	352	1	7	221	99	4
Other	1, 023	624	197	1	9	113	75	2
Total fractures	3, 672	2, 369	667	2	21	393	206	8
Traumatic amputations, avulsions, etc	1, 763	1, 302	198	1	2	158	101	1
Wounds, penetrating	6, 499	4, 142	1, 385	4	31	632	291	9
Wounds, perforating	3, 565	1, 997	630	1	23	667	239	5
Wounds, lacerated	1, 641	1, 033	271	------	7	240	90	------
Wounds, abraded or contused	69	49	14	------	1	4	1	------
Wounds, unqualified	1, 828	484	382	2	23	574	356	4
Crushing	109	41	38	------	5	16	9	------
Burns	263	106	51	1	9	65	27	1
Other traumatisms	1, 401	998	97	------	5	187	111	2

[1] Among cases who reached a medical treatment facility. Excludes those who died in enemy prisons.
[2] Includes 22 deaths in December 1941 among admissions in Central and South Pacific. Excludes 120 who died of wounds (TAGO source) in the Philippine Islands in 1941 and 1942.
[3] Includes 21 deaths among admissions aboard transports.

World War II progressed. Figures from the Office of The Surgeon General published in 1944 indicated that approximately 8 percent of casualties with chest wounds were dying as a result of their wounds. The Fifth U.S. Army surgeon's annual report for 1944 showed considerably better results (*12*). During 1944, the case fatality rate for Fifth U.S. Army field hospitals, in which the most severely wounded were treated, was 12.6 percent, but the rate in evacuation hospitals was 4.8 percent and for all Army hospitals 6.7 percent.

An analysis of the 2,267 intrathoracic wounds (including 903 thoracoabdominal wounds) treated by the thoracic surgical teams and other teams of the 2d Auxiliary Surgical Group (*14*) showed the effects of experience in what might be termed a learning curve. For the entire period in which this group was active, the operative case fatality rates (on U.S. casualties) for the periods prior to 1 May 1944 and after 1 May 1944 are as follows: trained thoracic surgeons 8.28 percent and 7.08 percent, respectively; against 13.17 percent and 8.82 percent for general surgeons, respectively.

TABLE 9.—*Number of admissions* [1] *for battle injuries and wounds of the thorax and thoracoabdominal region in the U.S. Army, by anatomic site and year, 1942–45* [2]

[Preliminary data based on tabulations of individual medical records]

Anatomic site	1942–45	1942	1943	1944	1945
Thorax:	*Number*	*Number*	*Number*	*Number*	*Number*
Thorax, generally	18, 918	255	2, 160	10, 221	6, 282
Thoracic wall, generally	6, 872	9	49	4, 538	2, 276
Posterior thoracic wall	5, 257			2, 931	2, 326
Axilla	1, 956	8	126	1, 152	670
Ribs	3, 082	28	305	1, 852	897
Heart:					
Heart, generally	33		1	15	17
Auricle, left	7			6	1
Auricle, right	13			11	2
Ventricle, left	22			13	9
Ventricle, right	33			20	13
Pericardium	59	1	1	32	25
Myocardium	10			6	4
Heart, other	5			2	3
Total heart	[3] (182)	[3] (1)	[3] (2)	[3] (105)	[3] (74)
Lungs	5, 075	3	50	3, 068	1, 954
Trachea	131		3	67	61
Bronchi	4			3	1
Mediastinum	69		3	37	29
Pleura	235		2	144	89
Thoracic duct					
Esophagus	30		1	16	13
Diaphragm	105		4	48	53
Thorax, other	1, 510	24	86	882	518
Total	43, 426	328	2, 791	25, 064	15, 243
Thoracoabdominal region	3, 233			1, 752	1, 481

[1] Excludes cases carded for record only.
[2] Includes admissions in December 1941. Excludes cases wounded or injured in action in the Philippine Islands in 1941 and 1942.
[3] Figures in parentheses are subtotals.

In the opinion of the surgeons who worked in the Mediterranean theater, the improvement in the case fatality rate and in the general results in thoracic wounds could be attributed in large part to the establishment of uniform and consistent policies of management for these wounds after March 1944 (p. 199).

BATTLEFIELD DEATHS

Surveys of the causes of deaths on the battlefield are infrequent. Only two seem to have been conducted in World War I. In 1916, Sauerbruch (*15*) reported that of 300 soldiers who died on the battlefield, 30 percent had wounds of the chest. In a similar survey of 469 battlefield deaths, Loeffler (*16*)

TABLE 10.—*Number of deaths*[1] *among admissions for battle injuries and wounds of the thorax and thoracoabdominal region in the U.S. Army, by anatomic site and year of admission, 1942–45*

[Preliminary data based on tabulations of individual medical records]

Anatomic site	1942–45	1942	1943	1944	1945
Thorax:	*Number*	*Number*	*Number*	*Number*	*Number*
Thorax, generally	2, 599	30	208	1, 369	992
Thoracic wall, generally	56			40	16
Posterior thoracic wall	135			80	55
Axilla	39			27	12
Ribs	147	2	5	119	21
Heart:					
Heart, generally	18		1	10	7
Auricle, left	1				1
Auricle, right	3			2	1
Ventricle, left	2			2	
Ventricle, right	5			4	1
Pericardium	14			9	5
Myocardium					
Heart, other					
Total heart	[2](43)		[2](1)	[2](27)	[2](15)
Lungs	450	1	1	265	183
Trachea	26		1	15	10
Bronchi					
Mediastinum	4			1	3
Pleura	9			6	3
Thoracic duct					
Esophagus	6			4	2
Diaphragm	53			25	28
Thorax, other	46			32	14
Total	3, 613	33	216	2, 010	1, 354
Thoracoabdominal region	698			436	262

[1] Consists of all admissions which ended in death, not necessarily due to the injury or wound causing admission or necessarily occurring during the years indicated. (The year shown is year of admission.)
[2] Figures in parentheses are subtotals.

reported that 29 percent had chest injuries. It is recognized that all statistics obtained in this manner are inaccurate. For one thing, the tagging of the bodies is done by medical corpsmen who are not qualified to make diagnoses. For another, many bodies are so badly mutilated that even professionally trained medical officers would often have difficulty determining the cause of death.

Special study.—The only study of battlefield deaths carried out in World War II covered the examination of 1,000 bodies. It was conducted by Capt. William W. Tribby, MC (*17*), and his associates of the 2d Medical Laboratory in four U.S. military cemeteries in Italy, between 29 April and 6 November 1944.

In his introduction to Captain Tribby's report, Brig. Gen. (later Maj. Gen.) Joseph I. Martin, then Surgeon, Fifth U.S. Army, stressed the difficulties under which the investigation was conducted. On numerous occasions, it seemed that lack of time, obstinately bad weather, the need for secrecy, the hardships of working under battlefield conditions, and the constantly changing military situation would all contrive to halt the work, which was being done as an additional duty by the hard-pressed personnel of a very active field laboratory. Unless these circumstances were understood, General Martin pointed out, the "monumental scope" of the undertaking also would not be realized.

The work was done in military cemeteries for a number of reasons, including the fact that the bodies were received in them in large enough numbers to make the investigation feasible within a reasonable period of time. The study was unselective, except for the requirement that the bodies be in fit condition for positive identification of the location and extent of the wounds.

Every wound was probed, and its extent was determined as exactly as possible, but all examinations were external. The inaccuracy caused by limitation of the investigation to external examinations was fully realized, but experience with the first few bodies, in which autopsy was attempted, proved that a continuation of the attempt would have made the investigation entirely impractical. Had autopsies been possible, numerous additional wounds might well have been found, particularly in bodies in which the wounds were too small to be probed satisfactorily.

In most instances, it was not possible to determine the position of the casualty at wounding; those who actually saw the death occur were usually not present when the body was tagged. In many instances, also, it was impossible to determine the wounding agent.

Chest wounds were defined, in addition to anterior wounds of the thoracic region, as all wounds located posteriorly above the level of the first lumbar vertebra and all wounds of the axillary region and the region of the shoulder girdle unless the injury extended into, or was distal to, the head of the humerus. These criteria generally agree with the definition of wounds of the chest suggested by Churchill (p. 59).

Data elicited concerning wounds of the chest in these 1,000 cases were as follows:

Of the 312 single wounds, 84 were in the chest.

In the 171 bodies in which the wounds were multiple and were confined to portions of the body above the diaphragm, 120 wounds of the chest were found.

The data show that 572 wounds of the chest were found either singly or in various combinations of injuries both above and below the diaphragm. No other region of the body above the diaphragm was affected more often than the chest. Next in order of frequency were the lower extremities, which were wounded in 327 bodies.

Of the 572 wounds of the chest, 422 (73.8 percent) were sufficiently grave to account, in themselves, for the fatality. Of the 2,385 wounds found in the 1,000

TABLE 11.—*Number of U.S. Army personnel killed in action* [1] *during 1942–45,*[2] *by anatomic location of wound and theater*

[Preliminary data based on tabulations of individual medical records

Anatomic location	All theaters	Europe	Mediterranean	Middle East	China-Burma-India	Southwest Pacific	Central and South Pacific	North America	Latin America	Transports
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Head	30, 599	18, 076	6, 836	9	154	3, 843	1, 471	204	2	4
Face	3, 266	2, 117	562	2	18	431	125	11		
Neck	3, 990	2, 361	926		11	476	182	34		
Upper extremities	2, 511	1, 540	557	1	8	288	105	12		
Thorax	17, 957	10, 707	3, 792	3	72	2, 416	816	148		3
Thoracoabdominal region	319	152	91		6	63	7			
Abdomen	12, 598	7, 764	2, 807	2	32	1, 349	545	99		
Pelvis	122	86	19			15	2			
Spinal column	278	174	38	1	4	52	7	1		1
Lower extremities	5, 492	3, 440	1, 448		9	411	153	30		1
Body generally	8, 821	4, 909	2, 098	21	280	1, 034	467	11	1	
Unreported	106, 267	68, 717	16, 011	300	2, 042	9, 044	8, 481	677	34	961
Total	192, 220	120, 043	35, 185	339	2, 636	19, 422	12, 361	1, 227	37	970

[1] Excludes persons in a captured status who were killed outright while trying to escape or by air bombardment, etc.
[2] Includes 221 killed in action in December 1941. Excludes 1,909 killed in action (TAGO source) in the Philippine Islands in 1941 and 1942.

TABLE 12.—*Number of U.S. Army personnel killed in action,*[1] *by anatomic location of wound and theater, 1944*

[Preliminary data based on tabulations of individual medical records]

Anatomic location	All theaters	Europe	Mediterranean	Middle East	China-Burma-India	Southwest Pacific	Central and South Pacific	North America	Latin America	Transports
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Head	18, 826	12, 979	4, 255	4	89	1, 105	390	2	2	----
Face	2, 124	1, 538	414	----	12	92	68	----	----	----
Neck	2, 480	1, 645	642	----	7	128	58	----	----	----
Upper extremities	1, 459	993	370	----	5	54	37	----	----	----
Thorax	10, 885	7, 469	2, 451	----	49	660	253	1	----	2
Thoracoabdominal region	252	131	89	----	4	22	6	----	----	----
Abdomen	7, 860	5, 588	1, 745	1	21	339	166	----	----	----
Pelvis	85	66	13	----	----	5	1	----	----	----
Spinal column	171	138	22	----	2	8	----	----	----	1
Lower extremities	3, 437	2, 385	941	----	4	75	32	----	----	----
Body generally	5, 344	3, 181	1, 609	3	131	327	91	1	1	----
Unreported	57, 340	40, 942	9, 152	4	1, 267	3, 532	2, 393	20	13	17
Total	110, 263	77, 055	21, 703	12	1, 591	6, 347	3, 495	24	16	20

[1] Excludes persons in a captured status who were killed outright while trying to escape or by air bombardment, etc.

bodies, 1,426 (59.8 percent) were sufficiently grave to explain why death occurred.

The diagnosis on the emergency medical tag proved erroneous in 276 of the 572 wounds of the chest (48.3 percent). This was the second smallest proportion of errors, the smallest proportion (35.7 percent) being in 154 of the 432 head injuries. These errors were, for the most part, inevitable: Accurate diagnoses could not be expected unless the body could be stripped of all clothing and examined by a medical officer.

The investigation was conceived as one further step to improve the protection of the soldier on the field of battle. It showed that in 202 of the 1,000 fatalities, the casualties could not have been saved from death by any type of body armor. Body armor, however, might well have averted a number of the 572 wounds of the chest in this series.

Official statistics.—Official figures for casualties killed in action and for those who died of wounds show a total of 213,976 according to the figures of The Adjutant General's Office and 213,030 according to those of the Office of The Surgeon General. The discrepancy is slight and seems to relate to the manner of classification of the deaths.

Of the 192,220 casualties killed in action whose wounds were classified by anatomic site (table 11), 17,957 (9.3 percent) had wounds of the thorax and 319 (0.16 percent) thoracoabdominal wounds. These figures for the 1942–45 period cover all theaters. The figures for 1944, the year in which the largest number of casualties occurred, are presented in table 12.

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Part II

ADMINISTRATIVE CONSIDERATIONS IN WOUNDS OF THE CHEST

CHAPTER III

Administrative Considerations in the Mediterranean (Formerly North African) Theater of Operations

Lyman A. Brewer III, M.D., and Thomas H. Burford, M.D.

THE CONSULTANT SYSTEM

A consultant in thoracic surgery was not appointed in any theater of operations during World War II. While this was unfortunate, in view of the number (p. 61) and gravity of thoracic and thoracoabdominal wounds, the results of the omission were not so serious as they might well have been:

1. Col. Edward D. Churchill, MC, Consultant in Surgery, Office of the Surgeon, Headquarters, Mediterranean Theater of Operations, U.S. Army, had a special interest, and a long experience, in this field, as did Maj. (later Col.) Howard E. Snyder, MC, Consultant in Surgery to the Surgeon, Fifth U.S. Army, which operated in this theater.
2. Col. Frank B. Berry, MC, Consultant in Surgery to the Surgeon, Seventh U.S. Army, was also particularly interested in this field.
3. In the Office of the Chief Surgeon, Headquarters, European Theater of Operations, U.S. Army, the Chief Consultant in Surgery, Col. (later Brig. Gen.) Elliott C. Cutler, MC, had been one of the pioneers in thoracic surgery.

It was therefore possible for all of these officers, while carrying out their general responsibilities as consultants in surgery, to supervise and encourage the work in thoracic surgery. Their functions included:

1. Evaluation, with recommendations for correction as necessary, of the physical conditions in which surgical patients were cared for.
2. Evaluation of equipment and supplies, with recommendations for such changes as were indicated.
3. Evaluation of the training, experience, and proficiency of medical officers to whom surgical duties were assigned, with recommendations for such changes of assignment of duties and of location as were indicated.
4. Establishment of the surgical procedures that could suitably be undertaken at each echelon of medical care and by different medical installations under varying tactical conditions.
5. Adaptation of evacuation procedures to the exigencies of surgical care, so that military necessities would interfere as little as possible with the welfare of all casualties.

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6. Recommendations for the deployment of surgical teams for routine and special missions.

7. Recommendations for the organization and staffing of special centers for the treatment of patients requiring specialized skills.

8. Introduction into the theater of new and approved methods developed in other theaters and in the Zone of Interior.

9. Dissemination of information on medical and medicomilitary matters to medical officers throughout the theater.

10. Preparation of circular letters and occasionally of command circulars.

11. Collection and interpretation of the overall experience in the theater as well as the experiences in special types of wounds and injuries and with special methods of treatment. Analysis of these experiences was perhaps the best method of evaluating the results obtained and comparing them with the results which might reasonably be expected under prevailing conditions.

These functions were discharged in various ways by the consultants in surgery. Their methods included inspection of hospitals, direct examination of patients, demonstrations of special techniques, formal and informal conferences with surgical staffs of the various medical installations, and planned meetings for division, army, and base area surgeons as military necessities permitted. Special educational efforts were directed toward indoctrination and orientation of surgeons accustomed to the practice of surgery in civilian life, or in the less urgent circumstances of the Zone of Interior, in the light of the different medicomilitary considerations that had to be taken into account in oversea theaters.

Important improvements in surgical care emerged from the stimulation of medical officers to collect and analyze their own results. Important sections of this and other volumes of the history of the U.S. Army Medical Department in World War II emerged from these studies.

THORACIC SURGERY PERSONNEL

Numerical shortages of thoracic surgeons existed in all theaters. Beebe and DeBakey (*1*), in their book on battle casualties published in 1952 and based on official records, estimated that if each surgeon were to operate on 7 casualties per day, nine thoracic surgeons would be required to perform initial surgery on each 1,000 wounded casualties. Even in the Mediterranean theater, where there were, proportionately, more thoracic surgeons than in any other theater, this ratio was never met.

Shortages of thoracic surgeons had to be made up in any manner possible. This meant using the limited number of experienced and well-qualified medical officers in this specialty to the best possible advantage, as described later in the discussion of auxiliary surgical group teams (p. 93). The most efficient solution of the problem was the proper assignment of the thoracic surgeons on auxiliary surgical group teams (p. 92). It was not possible to put surgeons

with training of only 3 or 4 months into positions of supervisory importance, no matter how carefully their training had been conducted.

The efficient use of thoracic surgeons was hampered by certain administrative roadblocks. By October 1944, the prediction had been amply fulfilled that special hospitals would be necessary for thoracic surgery and other surgical specialties. Yet at that time, the table-of-organization provision for thoracic surgeons was extremely limited. Constant difficulty was encountered in fitting these specialists into the inflexible hospital tables of organization and in supplying the additional help necessary to run a thoracic surgical service efficiently. The importance of this specialty, properly set up to function efficiently, was great enough to justify adequate table-of-organization provision for it in all echelons of medical care, yet neurosurgeons were provided for administratively long before thoracic surgeons.

Ideally, the personnel of a thoracic section in a thoracic surgery center consisted of a lieutenant colonel, who served as chief of section; a captain, who served as anesthesiologist; two captains, who served as surgical assistants and as ward officers; three surgical nurses; and three surgical technicians. Neither in rank nor in numbers was this ideal ever fulfilled.

EVACUATION AND TRANSPORT

In North Africa, nontransportable casualties were cared for in clearing stations (p. 216).

Development of Policies of Surgical Care

Sicily.—In Sicily, the first casualties on D-day were handled by the Navy, in beach stations set up in each of the six landing areas. They were then evacuated to ships offshore. In the next phase of the operation, beginning in the afternoon of D-day and continuing through the next 24 hours, Company C of the 261st Medical Battalion was landed and was followed by other units. After some difficulties because of the landing of equipment without personnel or vice versa, evacuation of casualties to the beaches and thence to the boats proceeded with remarkably little confusion. On D+2, casualties began to receive initial care in the clearing station of the 51st Medical Battalion, with surgical teams attached, or in Company A of the 261st Medical Battalion. On D+3, two platoons of the 11th Field Hospital began to receive and hold casualties.

These details are important:

This was the first time in this or in any previous war that casualties had been cared for in field hospitals adjacent to division clearing stations, with the intrinsic personnel of the field hospital platoons augmented by teams from an auxiliary surgical group. As a result of these arrangements, the nontransportable casualties of the augmented II Corps (now the Seventh U.S. Army)

received initial wound surgery within from 8 to 12 miles of the front. This plan, greatly expanded, was followed for the remainder of the war in the Mediterranean theater and was employed throughout the fighting in the European theater.

Anzio.—For a variety of reasons, the most serious medicomilitary problems encountered in Italy were met on the Anzio beachhead (Operation SHINGLE). Shore-to-ship evacuation of casualties was predicated on the orderly return of casualties to the beaches. In the initial landings, casualties were less than 1 percent of the troops committed instead of the estimated 12 percent. After 48 hours, however, the tactical situation worsened, and the medical situation along with it. The original locations of the hospitals that had been landed became untenable at once, because of continuous bombing and strafing of the beachhead area, punctuated by heavy enemy attacks at intervals. The hospitals were therefore relocated in open terrain, as far as possible from military objectives, but at the best, this was not very far. Since the beachhead was only about 7 miles in depth, the usual functional distinctions between field and evacuation hospitals could not be observed. Both were practically on the frontline. Hospitals were seriously damaged by heavy shelling, and there were also losses of medical personnel.

From the beginning of the Anzio operation, an attempt was made to care for all casualties before they were evacuated by LCT's (landing craft, tank) and boat ambulances to hospital ships. If recovery was expected within 14 days or less, the wounded, especially if they were experienced combat soldiers, were kept in evacuation hospitals. Otherwise, they were evacuated to the Naples area by boat. After 26 May 1944, they were frequently evacuated by air. Occasionally, when the casualty load was unusually heavy, patients who were transportable were evacuated to the base hospitals in the Naples area for initial wound surgery, which they thus received earlier than they would have if they had been kept at Anzio.

The Chain of Evacuation

Thoracic casualties, like all other casualties (fig. 3), were successively evacuated from the frontline, through the division area and the army area to the zone of communications. After the early fighting in Sicily, the chain of evacuation was as follows:

1. Casualties were brought by company aidmen to a battalion aid station (fig. 4), whence they were removed to a collecting company and then to a clearing station. Here, triage was carried out, and nontransportable casualties were transferred to the adjacent platoon of a field hospital, where the necessary surgery was performed.

2. Transportable casualties were transported from the clearing station to a forward evacuation hospital, where the necessary initial wound surgery was performed. The nontransportable casualties who had been cared for in the

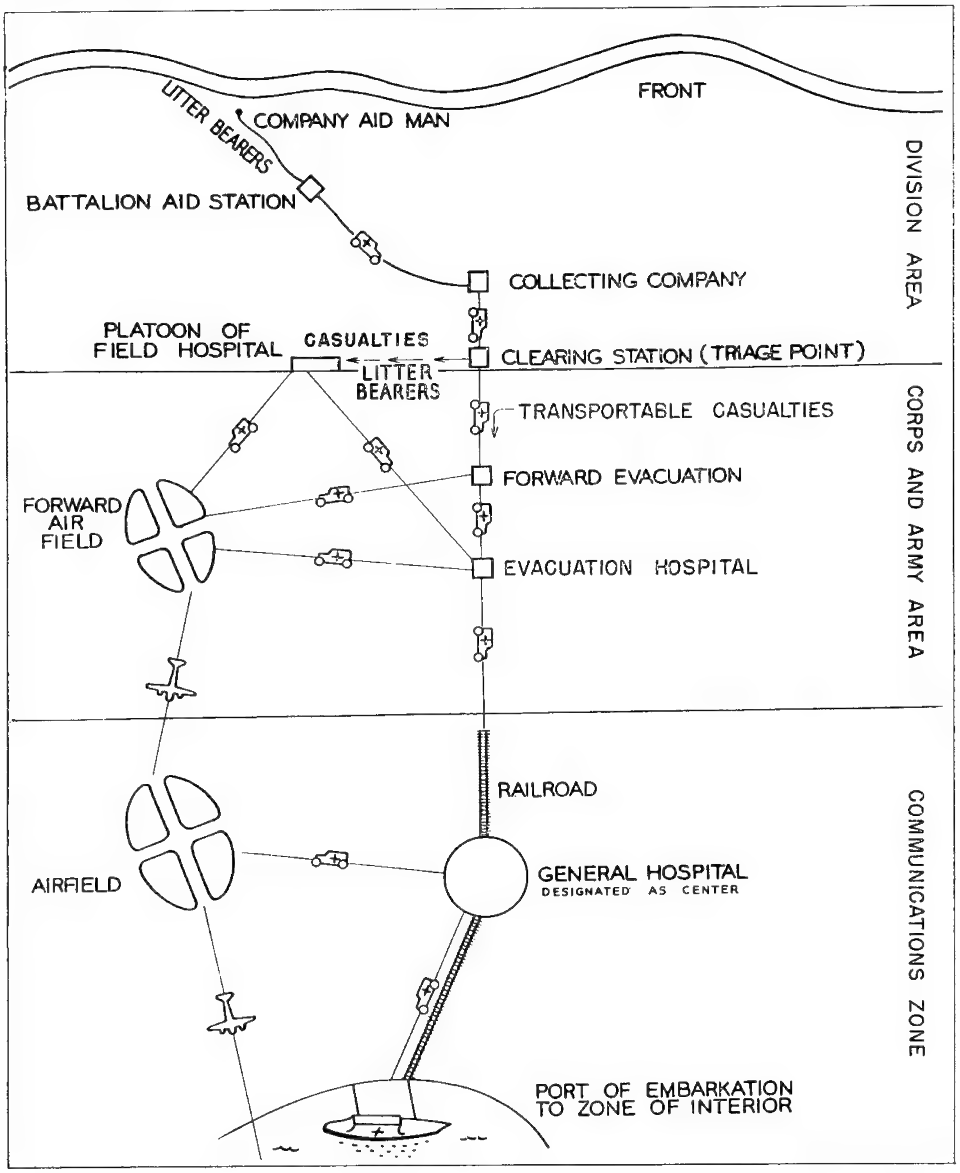


FIGURE 3.—Chain of evacuation in oversea theater to and from thoracic surgery center.

field hospital were later transferred to the evacuation hospital, after the appropriate period of convalescence.

3. Casualties in evacuation hospitals, after a longer or shorter stay, depending upon the nature of their wounds, the therapy necessary, and their response to it, were transferred to general and station hospitals in the communications zone or to special treatment centers.

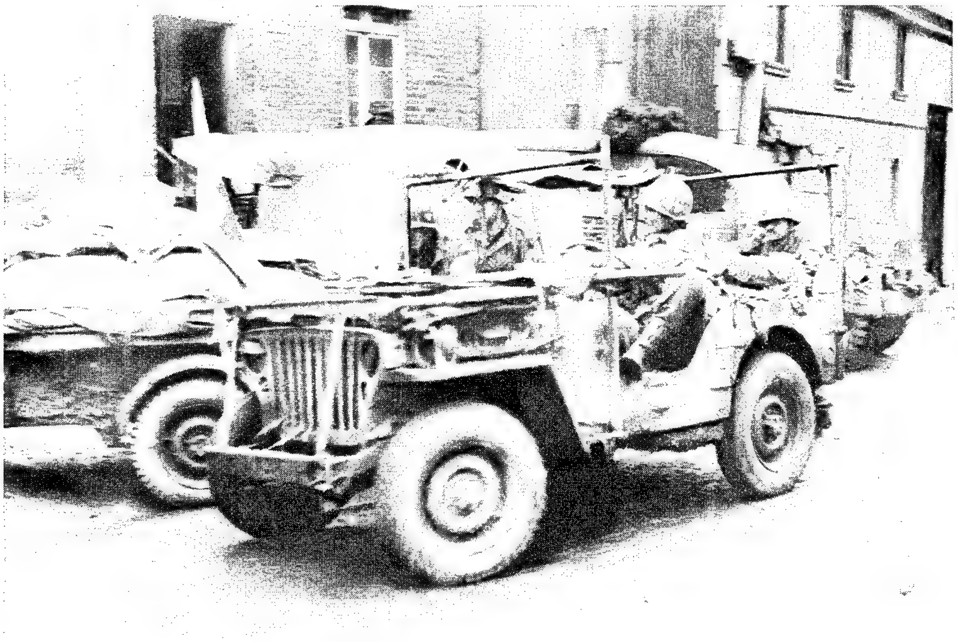


FIGURE 4.—Aidmen unloading wounded at battalion aid station in Italy.

4. From these hospitals, they were transferred to convalescent hospitals for rehabilitation before being returned to duty or were evacuated to the Zone of Interior from a port of embarkation or an adjacent airfield.

Transportation.—Litter carries and ambulances furnished the principal means of transportation from the frontline to battalion aid stations. Ambulances were used for transportation from the aid stations to the collecting and clearing stations. In mountain warfare, however, ambulances were useless in many areas, and the company aidmen had to move casualties by long litter carries, on muleback, and sometimes by cables strung between mountain peaks.

Ambulances were also used to move casualties from clearing stations or field hospitals in the division area to evacuation hospitals in the army area. The long ambulance hauls, over rough ground, that were often necessary in Tunisia, contributed materially to the state of shock in which many casualties were received in evacuation hospitals. Some died en route. In Tunisia, as well as during the first weeks of the fighting in Italy, some ambulance hauls were materially longer than they should have been because medical officers and ambulance drivers had inaccurate information about the location of hospital units nearest to the frontline.

Transportation difficulties were seldom serious in Sicily, and both evacuation and transportation were greatly improved in the Italian campaigns, particularly when hospital policies were clarified early in 1944. Hospital trains were first employed in Italy in November 1943.

Air evacuation.—After the Tunisian campaign, a questionnaire was sent to 38 medical officers working in evacuation, station, general, and convalescent hospitals, requesting their comments on methods of evacuation. Without a single exception, all of them recommended that air evacuation (fig. 5) be used for long hauls. Thoracic casualties came to consider it the preferred mode of evacuation.

Air evacuation was begun in Sicily about D+5. It proved a safe and expeditious way of removing casualties to hospitals in North Africa. It was particularly useful in moving casualties from the Anzio beachhead to Naples for reparative surgery and sometimes, as already mentioned, when the beachhead hospitals were crowded and the casualty load was heavy, for initial wound surgery. During the fall and winter of 1944–45, many casualties were transported by air from the field or evacuation hospitals at which they had received initial wound surgery to the 24th General Hospital in Florence, or the 70th General Hospital in Pistoia. Casualties with less serious injuries were flown to base hospitals in Leghorn and Rome. Most of these casualties were transported by means of C–47 (civilian DC–3) planes.

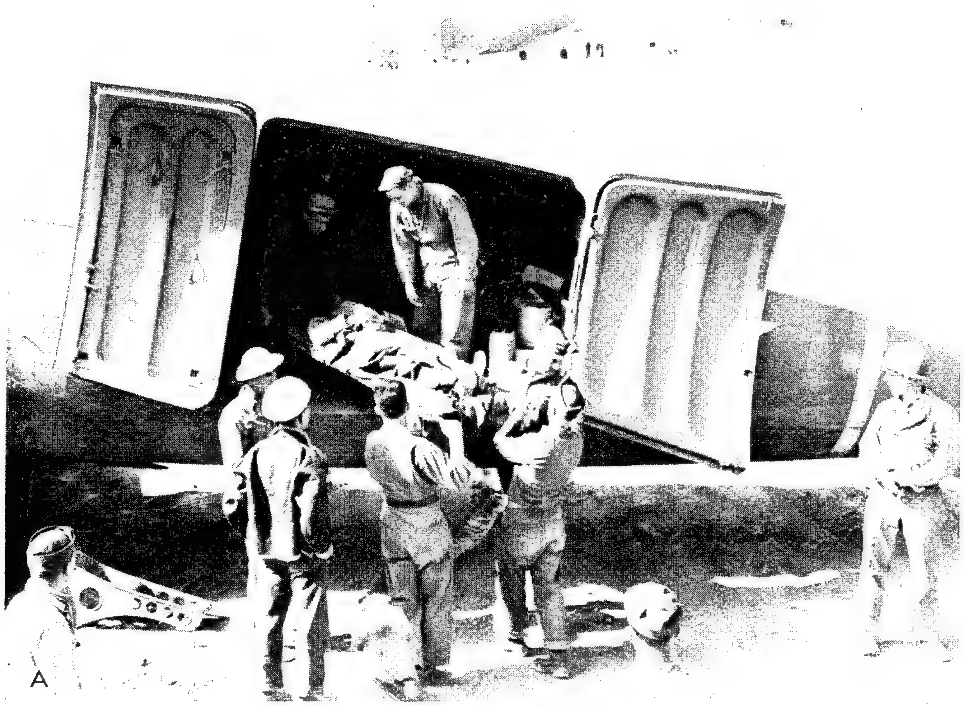
Air evacuation of individual patients by L–5 planes was begun experimentally in Italy early in March 1945. Careful selection was necessary, for no medical care was possible en route. These small planes proved extremely useful during mountain fighting and still later, when the Army broke out into the Po Valley. At this time, medical services, depleted by withdrawals for the Seventh U.S. Army, had to be spread over hundreds of miles.

Routine evacuation of thoracic casualties by air was not possible, since a high altitude flight in nonpressurized planes, with the consequent respiratory strain, might prove harmful, or even fatal, to patients with any degree of respiratory difficulty. With careful selection, however, most casualties tolerated flights at from 4,000 to 5,000 feet remarkably well.

TRAINING

There was no formal training in thoracic surgery in the Mediterranean theater, but a considerable amount of informal training was carried out. Lectures on the surgical and other aspects of the management of casualties were given by members of the surgical staffs of various hospitals to medical officers, nurses, and enlisted men. Because of the unusually large number of thoracic surgeons assigned to the 2d Auxiliary Surgical Group, these officers were frequently called upon to lead discussions and to give lectures and demonstrations on thoracic surgery. Newly arrived medical officers were attached to thoracic surgical teams for indoctrination and training, and other officers were attached to thoracic surgery services in general hospitals and to thoracic surgery centers for training in this specialty. A great deal of useful teaching was also done in field hospitals.

In 1944, the standards of thoracic surgery were greatly improved in a number of evacuation hospitals by the attachment to them, for from 1 to 3 months, of experienced thoracic surgical teams. During these periods, intensive



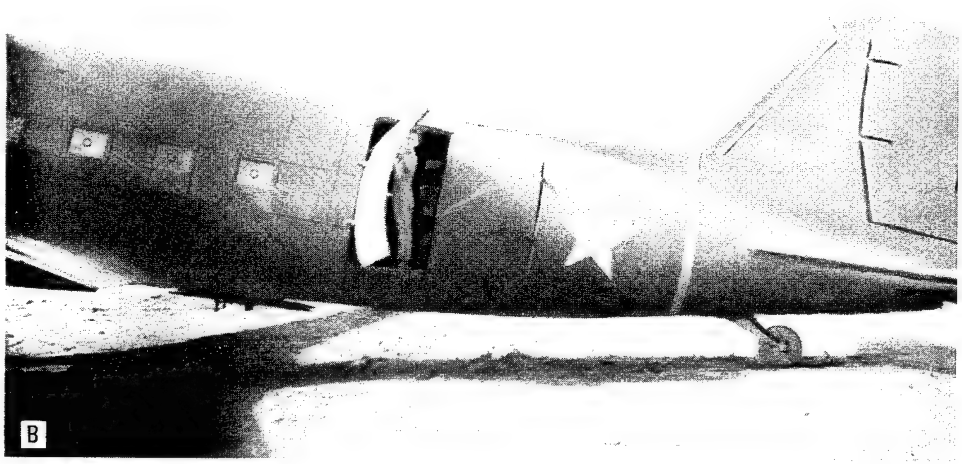


FIGURE 5.—Air evacuation of wounded in Italy. A. Transfer of casualties from ambulances to plane. B. Plane loaded and ready for takeoff to general hospital in base.

FIGURE 5.—Continued. C. Medical care en route.

efforts were made to teach the intrinsic surgical staff the refinements of management of thoracic and thoracoabdominal wounds. This was an extremely important and useful effort. All thoracic surgery on transportable casualties was handled in evacuation hospitals, and casualties with thoracoabdominal wounds sometimes reached evacuation hospitals from forward areas in which there were no intervening field hospitals. The surgeons in evacuation hospitals therefore had a great deal of thoracic surgery to do and had to be equal to the task.

All of these measures helped to alleviate, though they did not compensate for, shortages in trained thoracic surgeons. Of them all, none was more effective than the training given in thoracic surgery centers. In fact, from the long-range point of view, these centers were regarded as scarcely less important as instructional vehicles for the dissemination of the principles and practices of sound management of combat-incurred chest wounds than as specialized hospitals for the care of thoracic casualties.

Observation in British hospitals.—Some of the U.S. surgeons attached to hospitals which went into North Africa from the United Kingdom in November 1942 had been able to observe the work of British thoracic surgeons and to see some combat casualties. When the 77th Evacuation Hospital arrived in England in August 1942, Major Snyder, who was in charge of the thoracic

surgery section, requested permission for himself and the members of his section to go to London, to observe the work of Mr. A. Tudor Edwards, who was head of the thoracic surgical services of the British EMS (Emergency Medical Service). The original plans for a comprehensive 8- to 9-week tour of duty in British thoracic centers were delayed, and the invasion of North Africa was imminent when they were finally concluded. The extensive tour planned therefore had to be telescoped into 8 days. In the interim, however, Major Snyder had been able to work with Mr. Ronald Belsey, head of the thoracic surgical service at the Kewstoke Emergency Hospital (EMS) at Weston Super Mare, near Frenchay Park, where the 77th Evacuation Hospital was located.

During the official tour of chest surgery centers and clinics, the U.S. surgeons watched their British confreres in the operating room; made rounds with them; studied their preoperative and postoperative techniques; and attended their conferences, at which cases were presented, roentgenograms shown, and all phases of thoracic surgery covered. The information thus obtained proved of great value when combat-incurred injuries of the chest were encountered in North Africa a few weeks later.

CONFERENCES AND MEETINGS

Thoracic injuries were frequently discussed at the numerous conferences held in medical installations in all echelons in the Mediterranean theater, and several times the entire program was devoted to them. Colonel Churchill, in his visits to various installations in the theater, held what he called chautauqua meetings, to discuss various phases of military surgery. Because of his interest in the subject, his discussions of thoracic wounds always attracted considerable attention.

The first formal meeting in which thoracic surgery was discussed on the European Continent was held at Fifth U.S. Army headquarters in the King's Palace at Caserta on 11 November 1943.

In November 1943, Col. L. Holmes Ginn, Jr., MC, Maj. Floyd H. Jergesen, MC, and Major Snyder, Fifth U.S. Army consultant in surgery, talked to the medical staff of the 3d Division at a clearing station near Riardo. Their presentation and the ensuing discussion covered, among other subjects, the management of shock, the correct use of morphine, and the management of sucking chest wounds. Early in December 1943, Major Snyder discussed wounds of the chest before the surgical section of the 8th Evacuation Hospital. Later that month, Colonel Churchill, Consultant in Surgery, Mediterranean theater, addressed an all-day session at the 15th Medical General Laboratory, in Naples, on the general principles of wound management; a major portion of his remarks concerned chest injuries.

In February 1944, a meeting at the 38th Evacuation Hospital was devoted to this subject, with special reference to the management of wet lung, the use of atropine and morphine, and intercostal and paravertebral nerve block.

On 25 March, at the 401st Evacuation Hospital (French), an animated discussion was devoted (1) to hemorrhage, (2) to Pentothal sodium (thiopental sodium), which the French regarded as contraindicated in shock, and (3) to abdominal, thoracic, and maxillofacial wounds. On 30 March, at Marcianise, Italy, Major Snyder talked to the entire 2d Auxiliary Surgical Group on triage at the division clearing station, surgery in field hospitals, and chest surgery in field and evacuation hospitals. On 31 March 1944, a discussion at the 52d Station Hospital concerned surgery in forward hospitals and wounds of the chest. On the same day, a special meeting was held with thoracic surgeons of the 2d Auxiliary Surgical Group on the indications for chest surgery in forward hospitals (p. 200).

A special session of the Congress of the Central Mediterranean Force Army Surgeons held in Rome, 12–19 February 1945, was devoted to chest surgery.

Fifth U.S. Army medical conferences.—Chest surgery was a frequent subject at the Fifth U.S. Army medical conferences, which were held weekly, with very occasional exceptions, from their institution in the Royal Palace at Caserta on 11 November 1943 until just before the fall of Rome in June 1944.

The first of these meetings and the meeting on 24 February 1944 were entirely devoted to wounds of the chest. The participants in the first conference were Maj. (later Lt. Col.) Lawrence M. Shefts, MC, Maj. Lyman A. Brewer III, MC, Maj. (later Lt. Col.) Daniel A. Mulvihill, MC, and Maj. (later Lt. Col.) Henry K. Beecher, MC, who spoke on anesthesia for thoracic surgery. At the second conference, the participants were Maj. Benjamin Burbank, MC, Maj. Thomas H. Burford, MC, Lt. Col. Paul W. Sanger, MC, and Capt. Arthur J. Adams, MC, who spoke on anesthesia for thoracic surgery. The majority of the speakers at both of the conferences devoted entirely to chest surgery were heads of thoracic surgical teams of the 2d Auxiliary Surgical Group.

Other Fifth U.S. Army medical meetings devoted to such subjects as shock, hemorrhage, and anesthesia were also extremely useful in the development of policies on chest surgery.

All of these meetings proved a valuable means of disseminating information on chest surgery, particularly during the first winter (1943–44) in Italy, when educational needs were greatest. At this time, the front was generally stable, and Army medical installations were not too widely scattered. The Fifth U.S. Army medical conferences could therefore be attended by medical officers of all echelons in the Army area, as well as by many officers from station and general hospitals supporting the Fifth U.S. Army. The first meeting, as already mentioned, was held at Caserta. When headquarters moved forward, the conferences were held in one or another of the evacuation hospitals in the Army area.

EQUIPMENT

North Africa.—Equipment for thoracic surgery in the North African theater was originally poor. When the 77th Evacuation Hospital landed in England in August 1942, its equipment for this type of specialized surgery consisted of rib shears, a right and left rib raspatory, and a No. 14 F. ascites trocar. The explanation came later, in North Africa, when it was discovered from the newspapers in which the instruments and equipment for this hospital were wrapped, that the table of equipment was of World War I vintage, 1917 and 1918.

Observation at the British chest centers showed the type of equipment necessary for the proper management of combat-incurred wounds of the chest. It included long-handled instruments for work deep in the thoracic cavity, endoscopic equipment, various anesthetic agents (including cyclopropane), and the necessary equipment for the administration of these agents. The British also had cabinets to convert electrical current into high frequency current for cutting and coagulating and for converting current into low-tension current for use with endoscopic and other lighted instruments. A suction machine was attached to this cabinet, which thus took the place in U.S. medical equipment of (1) the Bovie apparatus for cutting and coagulation, (2) the suction machine, and (3) the battery case or rheostat that provided low-tension current for lighted instruments. The British considered this cabinet indispensable for chest surgery. Their mobile thoracic surgical teams in the United Kingdom had all the equipment just listed, and also had portable X-ray machines. Many months had to pass before U.S. Army thoracic surgical teams were as well equipped.

Medical officers of the 77th Evacuation Hospital personally purchased some of the equipment lacking for thoracic surgery, including a suction machine and a bronchoscope. When this hospital was assigned to the II Corps, for the invasion of North Africa, supply officers of the Corps, in spite of the purchase of supplies from British sources and other efforts, could not provide even the minimum equipment necessary for the competent performance of thoracic surgery. This hospital, and others similarly assigned, therefore went into North Africa in November 1942 with their equipment far inferior to that available to British chest surgeons.

Sicily.—There was great improvement in Sicily in the equipment provided for field hospitals, which were serving, for the first time, adjacent to clearing stations, but there were still shortages, including a lack of anesthetic machines. Major Snyder reported that Major Shefts, a member of a thoracic surgical team of the 2d Auxiliary Surgical Group, did most of his surgery under Pentothal sodium and oxygen supplied by a Boothby-Lovelace-Bulbulian mask, with extremely satisfactory results, though this variety of anesthesia is ordinarily regarded as contraindicated in chest surgery. Evacuation hospitals were much better equipped.

The portable hand-driven suction machines devised by Major Brewer and constructed from U.S. Army ordnance materials (figs. 6 and 7) were first used in forward hospitals in the Sicilian campaign. They proved very useful in tracheal and bronchial aspiration when electric power failed or was not available.

In Sicily, field hospitals had only a single X-ray machine for all three platoons, although each platoon, including platoons temporarily functioning

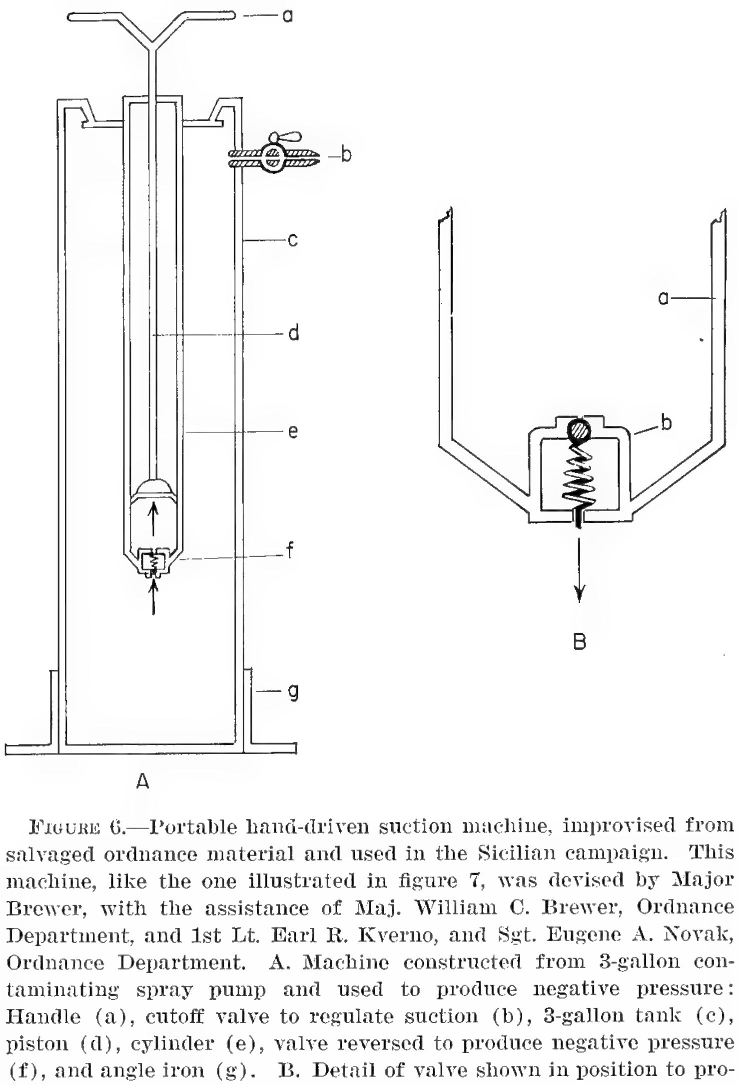


FIGURE 6.—Portable hand-driven suction machine, improvised from salvaged ordnance material and used in the Sicilian campaign. This machine, like the one illustrated in figure 7, was devised by Major Brewer, with the assistance of Maj. William C. Brewer, Ordnance Department, and 1st Lt. Earl R. Kverno, and Sgt. Eugene A. Novak, Ordnance Department. A. Machine constructed from 3-gallon contaminating spray pump and used to produce negative pressure: Handle (a), cutoff valve to regulate suction (b), 3-gallon tank (c), piston (d), cylinder (e), valve reversed to produce negative pressure (f), and angle iron (g). B. Detail of valve shown in position to produce positive pressure: Cylinder (a), and valve (b). In this position, the valve allows air to enter the tank and prevents its escape. In the position shown in view A, the air in the tank can escape but cannot reenter. Continued pumping of the piston exhausts the air from the tank and produces a vacuum.

as holding units, needed its own to function properly. In 1943, as already mentioned, films were in somewhat short supply, and restrictions were necessarily placed upon their unlimited use. In 1944, these restrictions were removed, and no chest casualty went to operation without adequate roentgenologic examination. Large dryers were also provided, so that dry processed films were ready when the patient went to the operating room.

Italy.—In Italy, after the first 6 months of combat, all hospitals came into the theater with modern, fully adequate equipment, and even the most forward hospitals were excellently equipped. Surgical instruments for all varieties of surgery, X-ray facilities, and anesthetic apparatus very closely approached those found in the best civilian hospitals. With the equipment used, as it was,

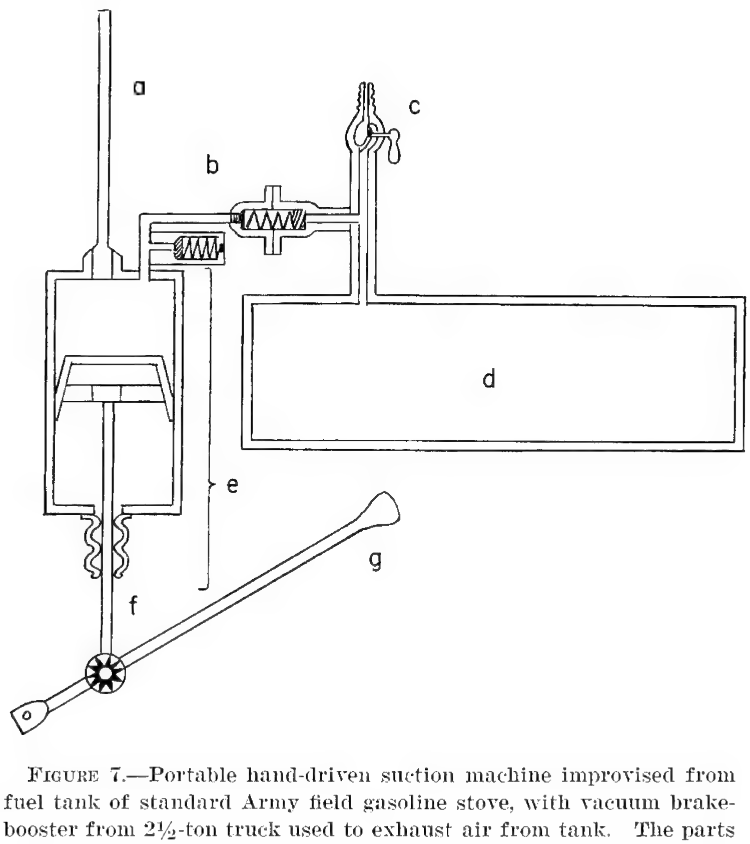


FIGURE 7.—Portable hand-driven suction machine improvised from fuel tank of standard Army field gasoline stove, with vacuum brake-booster from 2½-ton truck used to exhaust air from tank. The parts of the machine appear as follows: Support to fix pump (a), Bendix-Westinghouse air valves (b), cutoff valve (c), fuel tank from gasoline field stove (d), vacuum brake-booster (e), piston rod (f), and gear shift handle (g). This machine produced more suction than the machine described in figure 6 and was more easily operated. Both, in the absence of electrically driven suction machines, proved most useful in both operating room and ward tents for evacuating the tracheobronchial tree in chest and other injuries.

by well-qualified personnel, there was never any excuse for slipshod surgery in any field.

Shortages of equipment occasionally occurred till the end of the war, as the result of transportation difficulties. In the race across the Po Valley, for instance, in 1945, when supply depots and dumps were still back in Florence, the transportation of medical supplies sometimes had to make way for more critical needs, such as gasoline and ammunition.

Provision of the hospitals on the Anzio beachhead furnished special problems because of the local conditions. The supplies taken ashore in the original landings were brought in without incident. Later, supply dumps had to be abandoned because of losses caused by enemy shelling, and supplies had to be widely distributed.

Nonstandard equipment needed for thoracic and other specialized surgery in the Mediterranean theater was obtained on the authorization of the Fifth U.S. Army consultant in surgery, who, by direction of the Army surgeon, made his requests to the medical supply officer. Not all of the nonstandard equipment requested was supplied. Medical officers fresh from the civilian practice of surgery soon learned how to make do with the excellent and generally adequate equipment provided from late 1943 on.

There is no doubt that some credit for the good results of thoracic and other surgery in the Mediterranean theater must be attributed to good equipment. When equipment was in short supply, thoracic and other surgeons managed as best they could, making ingenious improvisations take care of deficiencies. At the beginning of the fighting in North Africa, for instance, the only suture material available was No. 0 and No. 00 chromic catgut. It was totally unsuited for pulmonary surgery, as well as for vascular and intestinal surgery. One thoracic surgeon supplied himself by having his wife send him some spools of cotton and silk thread from a 5- and 10-cent store. Later in the campaign, all types of suture material were available, including the atraumatic suture material (No. 0000 and No. 00000) particularly necessary for vascular surgery.

Thoracic Surgical Teams

Equipment.—When Major Snyder was placed on temporary duty in II Corps headquarters in March 1943, to report on the work of auxiliary surgical group teams in the Tunisian campaign, he made several recommendations concerning equipment for these teams, which then were doing surgery in clearing stations improperly equipped for this function (*2*). Two of the most important were for portable anesthetic machines and for more efficient apparatus for transfusions. He also recommended that teams be furnished with individual transportation.

In June 1943, after observing the surgical work in the chain of evacuation in North Africa and questioning many of the surgeons individually, Maj. Francis M. Findlay, MC, and Capt. Marion E. Black, MC, from Team No. 6,

FIGURE 8.—Jeep used with 1½-ton truck for transportation of personnel and equipment of 2d Auxiliary Surgical Group teams in Italy.

3d Auxiliary Surgical Group, reported to the Surgeon, II Corps, that the following equipment was essential for any surgical team to operate independently:

1. Adequate transportation assigned permanently to the team. The original system of depending upon other units for transportation was wasteful and unsatisfactory. A 1½-ton truck plus a jeep (fig. 8) or a command car would furnish complete transportation for personnel and all equipment. The enlisted men on a surgical team should be licensed as drivers.

2. Candle power (200 watts) for each operating table. In Tunisia, bulbs of this size had not been obtainable, and the most satisfactory substitute was a string of several bulbs of lesser wattage, set up by the electrician available in every hospital unit.

3. A portable oxygen apparatus, with a large cylinder reducing valve, and a Boothby-Lovelace-Bulbulian mask. This complete, efficient outfit was essential for all chest surgery. Army Air Corps medical officers already had this equipment.

4. A simple transfusion set for giving whole blood by the citrate method. The equipment should include large-gage (No. 15) needles as well as No. 13 needles. A very satisfactory transfusion set could be improvised, if these needles were provided, from aluminum tubing from airplanes, empty vacuoliter bottles, and tubing and filters from used plasma sets.

5. A large autoclave for sterilizing towels, gowns, and sheets. The upright British autoclave had three times the capacity of the U.S. Army type of pressure cooker being used for this purpose in some clearing stations.

6. Two covered metal sterilizers, each 18 inches long, for boiling instruments, gloves, and transfusion sets.

7. Two stoves for sterilizing. The Coleman stove, which burned leaded gas, though small, was quite efficient for this purpose. A third stove in reserve was a good asset, to heat water and to use in case one of the stoves in use broke down. Without heat, surgery had to stop.

8. Three large, 30-gallon galvanized GI cans, to use for washing, waste, and soaking dirty and bloody linen.

9. Linen, including 200 towels, 20 gowns, and 40 sheets. Drapes for the surgical tent were also necessary, to keep out dirt and dust.

10. A positive pressure apparatus of either the foot- or the hand-bellows type, or a portable anesthetic machine, which was useful even if anesthetic gases were not available.

11. The basic surgical instruments supplied to all teams.

12. A wall or pyramidal tent to furnish living quarters for the surgical team.

The necessity for making such a list points to the deficiencies in the original supply and equipment of auxiliary surgical group surgical teams. By the time the Italian campaign was well underway, all of these items, and many times even more efficient items, were in full supply. Eventually, the equipment of a thoracic surgical team consisted of an Army basic instrument set and a special thoracic surgical instrument and equipment set. The latter included not only all necessary instruments for chest surgery but also a suction machine (a portable suction machine had been a major deficiency originally), a portable anesthetic machine, a bronchoscope, and full equipment for therapeutic bronchoscopic aspiration. This equipment, like all equipment used by auxiliary surgical group teams, was severely tested in respect to both durability and serviceability by repeated sterilization and by the rapid moves necessary over air and water routes and by motor routes over difficult terrain. It stood up admirably.

Transportation.—Transportation for the teams of the 2d Auxiliary Surgical Group remained something of a problem to the end of the war. In the Tunisian campaign, the teams attached to the II Corps were furnished transportation that was turned in when the special assignment was completed. The same arrangements prevailed in Sicily.

In Italy, a certain amount of transportation was authorized for the 2d Auxiliary Surgical Group; it was maintained in a motor pool and assigned as necessary when the individual teams were moved. A few teams had independent transportation, which was far more satisfactory when fighting was heavy and rapid advances were necessary. When progress was slow, the need for independent transportation was, of course, less urgent.

The six by six truck was the most satisfactory vehicle, since all equipment and personnel could be transported in it. The jeep, in spite of its many advantages, could not accomplish this. It gave rise to so many difficulties, in fact, that surgeons of the 2d Auxiliary Surgical Group developed the habit of referring to it as Hitler's secret weapon.

BLOOD SUPPLY

U.S. medical officers found, as soon as they began to care for casualties in North Africa, how essential whole blood was for both freshly wounded men and for those with older wounds (*3*). The situation was not at all satisfactory. There were almost unlimited supplies of plasma, but the indications for its use were not nearly so extensive as had been anticipated. Whole blood was required, and it had to be obtained from clearing station and hospital personnel. Most units, furthermore, had come overseas with limited equipment for transfusion or with none at all. In the critiques of surgery in the Tunisian campaign, as already mentioned, attention was called to the need for more convenient methods of transfusion, and Major Snyder also pointed out that a source of blood other than noncombat personnel should be provided (*2*).

During the Sicilian campaign, as in North Africa, blood donors were secured from the personnel of hospital units or from neighboring service units, which was highly undesirable. Even these sources were not unlimited, for the frequency of malaria reduced the lists of available donors. Transfusion sets still had to be prepared, cleaned, and sterilized by hospital personnel, which took a great deal of time and was far from safe under field conditions.

By the end of 1943, most hospital units in the Fifth U.S. Army in Italy had provided their own small blood banks as a matter of necessity. Type-specific blood could be held in them for 24 hours, or, if necessary, a little longer. In February 1944, a central blood bank was organized, designed to supply whole blood to all Fifth U.S. Army units, and thereafter blood could be used in as liberal quantities as was considered necessary. A similar bank was set up in the Seventh U.S. Army before the invasion of southern France in August 1944.

The use of blood in thoracic casualties expanded as the supply of blood expanded, though it always had to be used with special precautions in these wounds (p. 253).

HOSPITAL INSTALLATIONS

Field Hospitals

Evolution of mission.—The evolution of the mission of field hospitals in World War II represents a major development in the care of combat-incurred wounds. In North Africa, these hospitals provided only the station type of

medical care. Surgery on nontransportable battle casualties was performed at the division clearing station.

In his report in April 1943 to Col. Richard T. Arnest, MC, Surgeon, II Corps, on the use of surgical teams in the Tunisian campaign, Major Snyder pointed out that the primary function of clearing stations was triage and that to perform surgery in them interfered with this function and also had elements of surgical risk (*2*). Furthermore, if triage was not correctly performed, nontransportable casualties might be classified as transportable and lose their lives as a result, while casualties who could be returned to duty if kept forward were likely to be evacuated to the rear and become lost for combat purposes.

Major Snyder recommended that thereafter platoons of clearing companies should be designated for surgical duties in an installation adjacent to clearing stations rather than within them. This arrangement would make it possible for seriously wounded casualties to be operated on without delay and would, at the same time, leave the clearing stations free to perform their basic function of triage.

Before the invasion of Sicily, this recommendation was advanced another step. In his evaluation of the work of the teams (2d Auxiliary Surgical Group) (*2*) which had been assigned to a British hospital in Algiers, Major Snyder had been greatly impressed with the fine work of these teams and with their potential usefulness in a combat zone. It was therefore planned that teams from the 2d and 3d Auxiliary Surgical Groups should be assigned to the 11th Field Hospital, which was to support the invading forces. During the latter part of the campaign, when the 10th Field Hospital also came under II Corps control and a platoon went forward to care for nontransportable casualties, it was promptly evident that its organic personnel could not handle the situation alone, and auxiliary surgical group teams were attached to it, as they had been to the 11th Field Hospital. Thereafter, surgical teams were attached to all field hospitals in the Mediterranean theater and were used in the same manner after D-day in Europe.

Concept and functions of field hospitals.—Field hospitals were operated on two concepts:

1. Some casualties, including those with thoracoabdominal wounds and certain types of chest wounds, as well as all casualties in deep shock, must receive surgical care at this level if they were to survive.

2. Casualties who had undergone the surgery required by such wounds must not be moved for a certain period of time, ranging from 8 to 14 days as a rule, and generally averaging 10 days.

About 10 percent of all casualties reaching a clearing station were nontransportable and required surgery in a field hospital at this level. Depending upon conditions of evacuation forward of the clearing station, casualties might be received within a few minutes after their evacuation from the battlefield; but as a rule, at least 1 or 2 hours had elapsed, and occasionally from 18 to 24 hours, or even longer, had passed since wounding.

The patients treated in field hospitals were frequently in desperate condition. Shock was profound, and heroic measures were often required to resuscitate them. The terms of reference under which these hospitals operated made it inevitable that the mortality rate should be high. Since the selection of patients for surgery at this level depended upon the triage performed in the adjacent clearing station, the importance of the function of the clearing station is evident. Without field hospitals, however, the mortality rate would have been still higher, and a surprising number of casualties operated on in them were returned to duty. An overall mortality rate of 25 percent was not unusual, while a rate less than from 12 to 20 percent strongly suggested that casualties who should have been operated on at this level had not been cared for there. If a field hospital was not accepting first priority (nontransportable) casualties or if other than first priority casualties were being accepted, it was not fulfilling the functions for which it was set up.

Field hospitals received patients, usually by litter carry, from the adjacent clearing station as soon as triage in them had been accomplished. The fundamental requirements for the performance of good surgery in them were:

1. Experienced surgeons, anesthesiologists, and operating personnel.
2. Good nursing.
3. Reasonable accommodation under shelter.
4. Adequate lighting and water supply.
5. Adequate equipment, including simple facilities for roentgenologic examination. One of Major Snyder's recommendations in his report to the Surgeon, II Corps, in April 1943 had been that clearing platoons designated to do major surgery should be better equipped than they had been in the Tunisian campaign (*2*). This recommendation was acted upon, and the field hospitals that handled forward surgery in the Sicilian campaign were far better equipped than the clearing stations that had performed the same mission in North Africa.
6. Facilities to retain patients for an average of 10 days after operation.

Physical setup.—The physical setup of a field hospital was fairly well standardized after its functions were standardized. The hospital was set up in ward tents, so erected that they formed a cross, the center of which was a pyramidal tent. The receiving and shock ward was located at the main entrance, with the postoperative ward directly opposite. The X-ray and laboratory equipment was in another ward tent, with the operating room directly opposite it. This compact arrangement reduced the movement of patients, concentrated supplies, made heating more efficient during the winter, permitted a complete blackout, and simplified nursing care.

Staffing.—The organic personnel of a field hospital, as already indicated, was not constituted, either numerically, frequently, or by training or experience, to do the sort of surgery assigned to these hospitals after the North African campaign and throughout the remainder of the war in the Mediterranean theater and in the European theater. The solution of the problem was

the attachment of teams from an auxiliary surgical group to field hospitals. As a rule, the intrinsic hospital personnel performed all administrative duties, and the attached teams performed most of the heavy major surgery required in medical installations located so far forward.

Each field hospital consisted of three platoons, each of which was staffed and equipped to care for from 40 to 50 newly wounded casualties, providing for them all services from resuscitation through postoperative care. While the number of teams attached was flexible, an active platoon required, as a rule, four general surgical teams, one thoracic surgical team, and one shock team. When their intrinsic staff was thus augmented, the number of surgeons and nurses provided in field hospitals was proportionately greater than in evacuation hospitals. This meant that seriously wounded patients could receive better individual attention and postoperative care than less seriously wounded casualties cared for in evacuation hospitals.

The establishment of field hospitals at the level of the clearing station proved highly advantageous for the morale of troops. Every man in a division thus supported knew that if he were seriously wounded, he would receive highly competent care and would receive it without delay.

At this level of medical care, segregation of injuries was not possible, if only because so many of them were multiple. Thoracic surgeons attached to field hospitals therefore had to have special qualifications. A thoracic surgeon must also be able to perform competent abdominal surgery; if no thoracic injuries required his attention, he had to undertake the care of casualties with abdominal and other injuries. In addition, a large percentage of thoracic wounds also involved the abdomen by continuity.

In view of the shortages of thoracic surgeons, it was often expedient, instead of attaching a surgical team to a field hospital, to attach a single thoracic surgeon. He performed the most serious operations himself, supervised other operations, supervised preoperative and postoperative care, and taught general surgeons the indications for, and the techniques of, thoracic surgical procedures. Many young general surgeons thus learned to do excellent thoracic surgery of the sort necessary in a field hospital. An experienced thoracic surgeon could also do much to elevate the standards of anesthesia for chest surgery in both field and evacuation hospitals.

Another possibility was to attach a senior thoracic surgeon to a field hospital and place two teams under his direction.

By whatever means the necessary personnel was provided, the proximity to the frontline of experienced thoracic surgeons (and other specialists) made it unnecessary for medical officers in clearing companies to indulge in heroic surgery for which their installations were not designed and for which they themselves were not trained.

A single thoracic surgeon could not usually handle all of the thoracic and thoracoabdominal surgery in a field hospital, even after indications for forward surgery were standardized. It was agreed that certain types of penetrating and perforating wounds which had earlier been considered first priority (non-

transportable) problems could quite as well be handled in evacuation hospitals (p. 199). Even then, the number of thoracic injuries which required forward surgery was still large. In one unselected series of cases encountered during a 7-week period in a platoon of a field hospital in the Mediterranean theater, 92 patients had intrathoracic wounds that made them nontransportable (22 thoracoabdominal wounds, 16 wounds requiring formal thoracotomy, and 56 other perforating or penetrating wounds). During the same period, the thoracic surgical team that cared for these patients also cared for 44 patients with abdominal wounds.

Postoperative function.—At the beginning of the fighting in North Africa, the tendency had been to place the chief emphasis upon the operative act and to regard most patients as transportable almost immediately after operation. It was promptly evident that casualties who were moved too soon after major surgery might be in worse status than if surgery had been postponed until an evacuation hospital was reached. In short, it was learned in military surgery, at bitter cost, just as it had been learned in civilian surgery, that complete postoperative care is quite as important in the surgical result as is the operation itself. The hospital on wheels was an alluring concept but totally impractical. Surgery was not practical beyond the point at which facilities for aftercare could be provided.

Holding patients after operation was reasonably simple in both field and evacuation hospitals when the hospital was located behind a stable front or a slowly advancing front. In these tactical circumstances, one field hospital could serve two divisions in the line by using two of its three platoons at two division clearing stations. The third platoon held patients at a fixed location until they were all evacuated, then leapfrogged over one platoon or the other to set up beside the clearing station that had moved forward.

When the front was moving rapidly, the postoperative situation was difficult and much more complicated. Every division then usually required the support of an entire field hospital, the platoons of which were set up in depth behind the front. Only the most forward platoon, adjacent to the division clearing station, received casualties. The other two platoons held patients in various stages of postoperative recovery until they could be evacuated and the platoons could move forward. When the forward platoon was closed to admissions, as it was when the clearing station adjacent to it moved forward, the rearmost platoon, whose patients had been operated on before those in the middle platoon, leapfrogged over the middle platoon to take its place alongside the clearing station in its new forward position. The platoon which had closed its admissions cared for its patients until they could be evacuated and it, in turn, could leapfrog forward and again receive patients.

In the beginning, only a skeleton staff was left with the platoon holding patients after operation. It was soon found that this was not adequate, for it made no provision for the management of complications and emergencies. The plan was then developed of leaving a surgical team with this platoon. It

was also found necessary to leave facilities for roentgenologic examination and for surgery, which meant a complete operating room setup.

When field hospitals were urgently needed during active campaigns, an evacuation hospital sometimes moved to the site occupied by the holding platoon and took over its postoperative duties in addition to its own responsibilities for initial wound surgery. The holding platoon could then move forward and again receive casualties.

Evacuation Hospitals

Mission.—Evacuation hospitals (fig. 9) were located from 3 to 15 miles behind field hospitals in Italy. In Tunisia, the distances had frequently been considerably greater. After it had been established that thoracic casualties withstood transportation well, the majority were treated in evacuation hospitals. Most of them came directly from clearing stations, but a small number were received from field hospitals, in which resuscitation had been instituted in the shock wards.

Evacuation hospitals were of two types, 400-bed and 750-bed. The larger capacity was often an advantage, but 400-bed hospitals, if reinforced by the appropriate number of teams from auxiliary surgical groups, were capable of

FIGURE 9.—Tents used for officers' quarters at 11th Evacuation Hospital, Anzio, Italy, in May 1944, dug in for protection from shellfire. On this beachhead, evacuation hospitals were so far forward that they served as field hospitals and frequently came under heavy fire.

handling about the same number of casualties as 750-bed hospitals not thus reinforced. The smaller hospital, with extra bed capacity provided in the form of an adequately equipped clearing platoon, was far more efficient in a fluid tactical situation than a larger hospital. A 400-bed semimobile evacuation hospital, because it could be rapidly moved to a new location, proved a particularly practical unit in Sicily, where frequent changes of position were required.

The clearing platoons were left as holding hospitals when the parent hospitals moved forward. It was quite as important to hold patients after major abdominal and thoracic surgery in an evacuation hospital as after surgery in a field hospital.

When the load on field hospitals increased, evacuation hospitals received more seriously wounded casualties than in nonpeak periods, which meant that they received more thoracic casualties. The general policy, whenever it was practical, was to send the most seriously wounded patients to the most forward evacuation hospitals. It was not a desirable plan to send patients to evacuation hospitals who should have been treated in field hospitals, but it was sometimes an operational necessity, as during the Anzio phase or during the pursuit of the Germans north of Rome after that city fell. Very careful selection of patients was obviously necessary when this policy was employed.

The extent to which other than urgent intrathoracic surgery was done in evacuation hospitals depended upon the tactical situation as well as upon the distance between them and the fixed hospitals in the communications zone. Transportation facilities also had to be taken into account.

It was fundamental policy that evacuation hospitals must not engage in the performance of semielective surgery when there was any chance at all that their bed capacity would be required for battle casualties. In quiet periods at the front, however, and sometimes when evacuation facilities to the rear were slow and uncertain, certain surgical procedures usually reserved for base section hospitals were undertaken in them. These procedures included the removal of intrapulmonary foreign bodies and, very occasionally, pulmonary decortication for organizing hemothorax. One justification for this type of surgery in an evacuation hospital was that the patient might be returned to duty from it.

This policy was chiefly used in North Africa, when hospital policies were not yet stabilized, and to a lesser extent in Sicily. During the Italian campaign, after the establishment of general hospitals, these surgical procedures were almost always reserved for these hospitals or for thoracic surgical centers.

Staffing.—When triage in the clearing station was efficient, evacuation hospitals received almost no abdominal or thoracoabdominal wounds, but they did receive the larger number of penetrating and perforating wounds of the chest, which frequently were associated with wounds of the extremities.

At this echelon of medical care, segregation of casualties for specialized management was entirely practical. Thoracic surgical teams proved particularly useful both in supplementing the thoracic surgical section of the hospital and in furnishing qualified personnel if there were no experienced

thoracic surgeons on the intrinsic staff. During peak periods, it was desirable to have two thoracic teams functioning in an evacuation hospital and devoting their chief, if not their entire, attention to the treatment of wounded whose major injuries involved the thorax. Preoperative and postoperative care of these patients was the responsibility of the thoracic surgeons, and they also supervised the care of the thoracic wounds in patients on other wards who had multiple wounds, some of which took precedence over the chest wounds.

Fixed Hospitals

Mission.—General and station hospitals in the base area received thoracic casualties as soon as they could be transported to the rear from evacuation hospitals. The time of the transfer depended on the nature of the wound and the surgery that had been necessary for it in the forward hospital.

The policies that governed the management of thoracic and other casualties in fixed hospitals in the base were worked out at the base section in Bizerte in the North African theater during 1943. The mission of these general hospitals in respect to thoracic casualties was threefold:

1. To perform the final reparative surgery on wounded casualties who could be promptly returned to duty. From the military standpoint, the most important function in the base was the energetic treatment of this group of patients, most of whom had wounds limited to the chest wall or wounds without severe intrapleural involvement. Sometimes patients with clotted hemothorax fell into this category. The principal operations performed were delayed primary wound closure; thoracentesis, if hemothorax still persisted; and decortication. Later in the war, decortication was practically always performed in chest centers.

Whenever a choice had to be made from the standpoint of time, available surgical personnel, or facilities, the final care and rehabilitation of patients in this group had the highest priority unless, of course, other patients would have suffered from a delay in their treatment. It was a matter of great importance that soldiers whose return to duty seemed probable should receive treatment as far forward, and as promptly, as possible. The farther from the front a casualty was moved and the longer his return to it was delayed, the less inclined he was to return to active combat.

2. To improve the morbid state of more severely wounded patients, to make them transportable to the Zone of Interior. Since these soldiers were no longer useful in the theater, the sooner they could be prepared for evacuation to the United States, the less was the drain on theater resources.

Casualties from Sicily were evacuated to North Africa before being sent to the Zone of Interior, and the same routine was followed in the early days of the fighting in Italy, before Italian ports were open. Seventh U.S. Army casualties, even after the Army passed into control of the European theater, were evacuated to the 21st General Hospital in Mirecourt, then to a general hospital in Dijon, and finally to Marseilles.

3. To preserve thoracic function and prevent chronicity and deformity. The preservation of physiologic function was the major objective in all casualties treated in the base, just as it was in the forward area. The institution of correct therapeutic measures prevented ultimate deformity of the lungs, heart, chest wall, diaphragm, and shoulder girdle. As a result of these measures, plus the absence of intrinsic (postpneumonic) infection, the number of so-called thoracic cripples after World War II was very small as compared with the very large number, absolutely and proportionately, after World War I (vol. II, ch. XI).

The management of thoracic casualties in the base areas permitted the continuity of treatment essential to avoid infection. The mission of hospitals in the base area was fundamentally to minimize the incidence and gravity of this and other complications. If a delaying or expectant policy was followed, the immediate mortality rate perhaps did not vary greatly from the rate associated with active therapy, but the degree and frequency of permanent disability was inevitably higher. A hemothorax, for instance, not completely evacuated in the forward hospital, was not likely to develop into hemothoracic empyema if it was treated promptly in the base hospital. Decortication could be done with minimal risk and a high expectation of good results. If the removal of foreign bodies was indicated, it could be undertaken before infection developed or pulmonary function was permanently reduced.

While the functions of base hospitals were generally as described, the tactical situation sometimes required that they assume other missions. These hospitals were occasionally far enough forward to receive freshly wounded patients, while during the first few days after a landing or other operation, particularly when air evacuation was possible, casualties also occasionally received initial wound surgery in them.

Thoracic Surgery Centers

Establishment.—Their early experience with thoracic casualties in North Africa convinced Major Burford and Maj. (later Lt. Col.) Paul C. Samson, MC, that the only really efficient way to handle these patients would be in thoracic surgery centers (fig. 10) equipped for this type of surgery and staffed by thoracic surgeons. Major Burford's first specific assignment in North Africa had been at the 21st General Hospital, then at Bou Hanifia, which had been receiving heavily infected thoracic casualties, consisting of both U.S. Army wounded personnel and German prisoners of war. It was here, incidentally, that he did the first decortication and established the precedent for the management of clotted and infected hemothorax and hemothoracic empyema in World War II (p. 27).

His own observations convinced Colonel Churchill of the soundness of Major Burford's and Major Samson's position, and the management of tho-

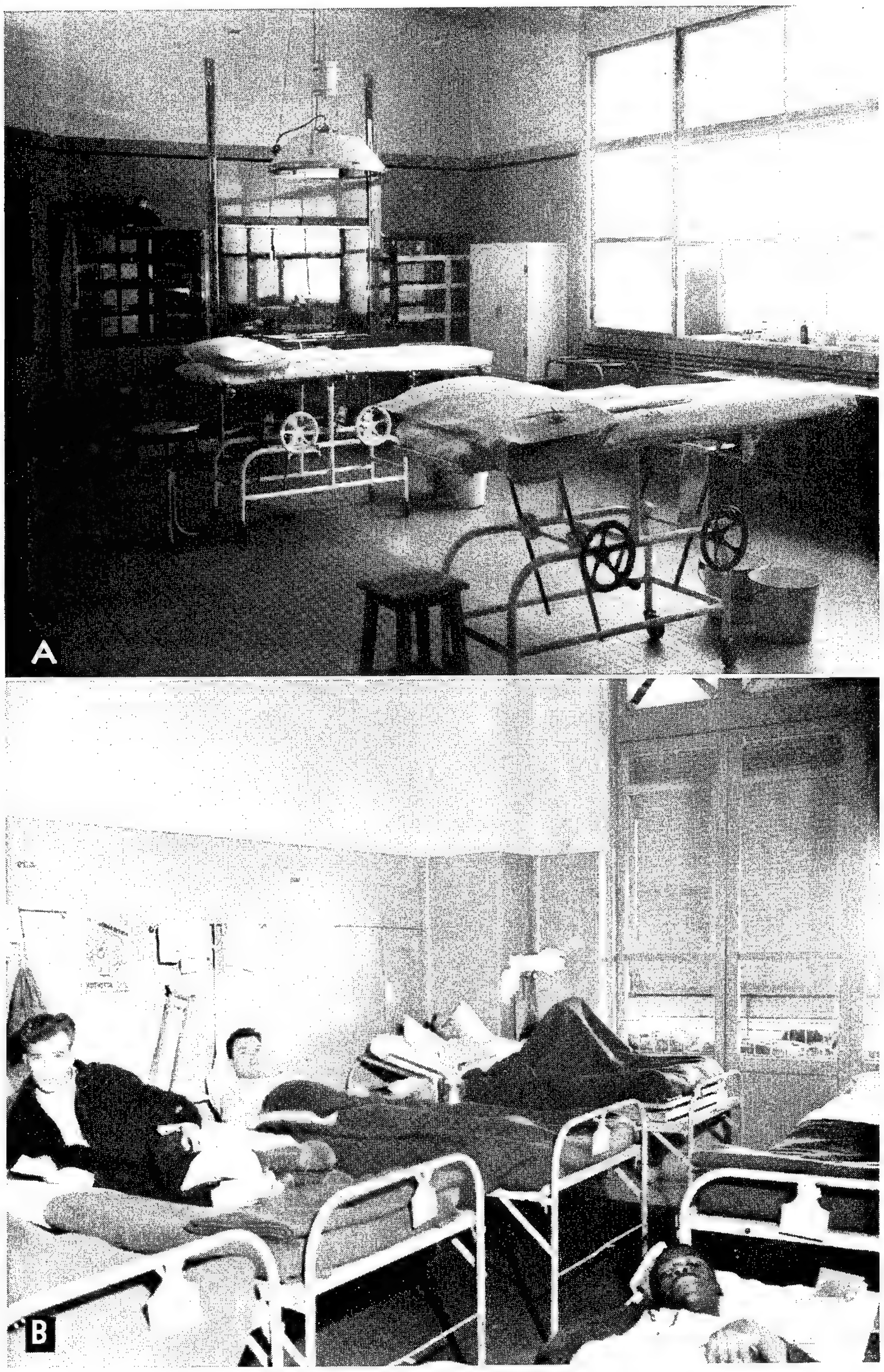


FIGURE 10.—Thoracic surgery center, 300th General Hospital, Mediterranean theater. A. Main operating room. B. Typical ward.

racic casualties in chest centers became standard policy in the Mediterranean theater throughout the war.

The first such chest center was set up on 7 July 1943 in the 53d Station Hospital at Bizerte (*4*), where the 53d and other hospitals, commonly referred to as "hospital row," were already in operation. At the request of the surgeons who made up the thoracic surgical staff of this center (Major Burford, Major Samson, and Captain Brewer), an internist, Major Burbank, was also attached to the service. This center received casualties from evacuation hospitals and from general hospitals in North Africa. After the invasion of Sicily, in July 1943, some freshly wounded casualties were flown directly to it.

There was almost no overlapping of the operation of chest centers in the Mediterranean theater, the policy being that not more than one should function at any one time. When the center at the 53d Station Hospital was closed at the end of October 1943, the 28 patients then hospitalized were transferred to the 24th General Hospital, also at Bizerte. The Salerno landings had been made in September, and casualties were then being received from Italy. This center was closed on 31 January 1944, just after the Anzio invasion, and the next center was established in Italy, at the 17th General Hospital located near Naples.

When the center at the 17th General Hospital was closed in March 1944, its functions were assumed by the 300th General Hospital at Naples. The last center to be established during the war was opened in March 1945, at the 70th General Hospital, located at Pistoia, just before the drive on Bologna. The hospital was at first so close to the frontline that during the first few days of the drive, it functioned, for all practical purposes, as a field hospital, and thoracic casualties were received shortly after they had been wounded.

The first chest center in the Mediterranean theater was established at a station hospital, but it promptly became evident that the limited bed capacity and the lack of certain essentials for the proper care of thoracic casualties made hospitals of this type unsuited to serve as thoracic surgery centers. All centers subsequently established were therefore at general hospitals. The influx of casualties to the centers proved the wisdom of this change of policy. The facilities of general hospitals were required to meet the variegated problems of a large specialty service dealing with difficulties of the magnitude encountered in combat-incurred chest injuries.

When the policy of chest centers was instituted, it was necessary to change the lines of evacuation (fig. 3) so that thoracic casualties would be evacuated from evacuation hospitals to the centers, without the delay and wasted motion involved in their going first to general hospitals. There was no selection of cases. Casualties sent to the chest centers represented an overall distribution. As a result, the observations made in the centers in the Mediterranean theater have a validity that was not possible when centers were used only as the last resort for patients with complicated and intractable wounds.

The system of staffing and operation evolved in the thoracic surgery centers and other centers for specialized treatment established in the Mediter-

ranean theater served as a pattern for the similar centers later established in the European theater, both in the United Kingdom Base and on the Continent.

Advantages.—The establishment of centers in base section hospitals for the study and treatment of specialized surgical problems had the same far-reaching influence on thoracic surgery that this policy had on other specialties. There were a number of obvious advantages:

1. The concentration of casualties with thoracic wounds under one roof meant that the thoracic surgeons, who were in such short supply, could be assigned to these centers and could use their talent and experience with the greatest economy and most effectively. This was a serious consideration. At the end of 1943, aside from the thoracic surgeons in auxiliary surgical groups, there were, at the most, six surgeons in the 17 hospitals in the Mediterranean theater who were qualified by training and experience to handle complicated thoracic wounds.

2. The concentration of thoracic casualties under trained personnel in a hospital with specialized equipment provided better opportunities for their observation and care than was possible when they were scattered through the general hospitals in the theater.

3. The opportunity of studying large numbers of casualties permitted an objective evaluation of the efficiency of previous treatment. It was then possible to alter therapeutic policies when they were not proving effective. The constructive criticisms that emerged as the result of these evaluations were disseminated to other installations by Colonel Churchill and others designated by him for this duty. They were also disseminated by means of circular letters. Numerous new techniques, of which decortication is an outstanding example, were thus introduced and standardized.

4. The establishment of special centers made possible the best timing for the reparative phase of the management of thoracic wounds. Numerous soldiers were returned to duty in the theater because their wounds were closed at the optimum time and, when indicated, retained foreign bodies were removed. Numerous empyemas were prevented because decortication was carried out at the optimum time in massive organizing hemothoraces. Many operations for which the optimum time had arrived before transportation to the Zone of Interior was available were also carried out in these centers.

5. As a result of these various policies, treatment was expedited as well as made more effective. The incidence of infection in thoracic casualties received in general hospitals and managed in them by surgeons without experience in chest surgery provided additional proof of the wisdom of, and necessity for, the policy of establishing chest centers. Manpower losses were diminished. Disposition of patients was accelerated, and the number of soldiers who could be returned to active duty in the theater was greatly increased. Finally, the crippling sequelae of chest injuries, which had been a continuing problem after World War I, furnished only minimal problems in World War II.

6. Not the least advantage of the thoracic surgery centers was the means they afforded for training younger officers with general surgical experience in

chest surgery and in preoperative and postoperative management of thoracic casualties. These officers, as already pointed out, received concentrated experience, under supervision, which they could not possibly have obtained if they had had to take the entire responsibility for the small share of chest injuries that would have come under their observation if the casualties had been scattered diffusely through the general and station hospitals of the theater.

Special experiences.—The thoracic surgery centers in the Mediterranean theater cared for a total of 1,538 intrathoracic wounds during World War II. The first centers established, the 53d Station Hospital and the 24th General Hospital, together treated 390 thoracic casualties, with the aid of Thoracic Surgical Teams Nos. 2 and 3 and Miscellaneous Team No. 1 from the 2d Auxiliary Surgical Group. These figures include 26 cases of thoracic disease, of which 22 were spontaneous idiopathic pneumothorax. In the remaining 364 cases, the wounds were limited to the chest wall in 185. There were 83 fractured ribs; 188 instances of traumatic hemothorax, pneumothorax, or hemopneumothorax; and 16 instances of blast lung (the figures are overlapping).

There were 3 deaths among the 390 patients. Of the survivors, 100 were returned to duty or to convalescent hospitals with the expectation that they would be returned to duty; 104 were evacuated to the rear and were probably later evacuated to the Zone of Interior; and 124 were transferred to other services or to other hospitals for active therapy. When the center at the 24th General Hospital was discontinued on 31 January 1944, 59 patients were still hospitalized, not all of whom were hospitalized because of their thoracic wounds. It should be remembered that even in a thoracic surgery center, the presence of other wounds frequently made certain modifications, sometimes not altogether desirable, necessary in the management of chest injuries.

AUXILIARY SURGICAL GROUPS

Early Concepts

In 1943, while the 2d Auxiliary Surgical Group was still at Lawson General Hospital, Atlanta, Ga., its commanding officer, Maj. (later Col.) James H. Forsee, MC, prepared an article on the management of thoracic combat-incurred injuries with two of the group thoracic surgeons (Major Shefts and Major Burford); an internist (Major Burbank); and an anesthesiologist (Maj. Leo J. Fitzpatrick, MC) (*5*).

The statements in this article about administrative considerations in chest injuries were to prove prophetic:

1. The single factor which can reduce the high mortality of chest injuries as recorded in previous wars is earlier definitive treatment by trained thoracic surgeons.

2. To effect this in the mobile type of war now occurring, it is necessary to have an equally mobile system of evacuation and management, which is

flexible enough and mobile enough to handle casualties soon after their injuries are incurred.

3. To accomplish these results requires the special training of surgeons and their assistants in the care of chest wounds. It also requires an organization whereby such personnel are available on short notice to function in properly equipped medical installations at the point of maximum casualties close to the battlefront.

4. Since there are too few specialists in thoracic surgery of field age to staff all hospitals, the deficiency must be remedied by the training of general surgeons in the fundamentals of thoracic physiology, preferably in hospitals in which chest cases are concentrated. Centers of this sort would also permit training in bronchoscopy and provide training for anesthesiologists in the techniques of endotracheal and positive pressure anesthesia, both essential for safe thoracic surgery.

5. Reduction of the timelag after wounding, which is also concerned with distance, resolves itself into (1) having the surgeon immediately available behind the frontline, even if it is a rapidly moving line, or (2) evacuating the wounded to him by ambulance or airplane.

Such a program of early definitive treatment by trained personnel, the authors concluded, would reduce the mortality of thoracic injuries, decrease their morbidity, reduce the hospital stay days, and eliminate a large proportion of the patients with chronic empyema who linger on long after a war is over. These so-called thoracic cripples are the obvious result of treatment applied late and frequently applied incorrectly. The elimination of this group of patients, who would require hospital care for many years, would have the additional advantage of accomplishing enormous monetary savings.

Implementation of Concepts

This statement of principles for the most part was translated into action in World War II (*6*). Never before in history had battle casualties received such prompt surgical care by such highly skilled specialists. This was made possible by two policies. The first was the provision of medical service in the combat zone in such locations that the period between wounding and competent surgical care was decreased. The second was the availability of young, formally trained medical officers, who were not only well qualified technically to perform good thoracic surgery but who, even more important, were schooled and grounded in the fundamental principles upon which good surgical practice is based.

The availability of these highly trained surgeons was a reflection of the carefully nurtured system of postgraduate medical education in the United States. Their superior performance was a measure of the progress made in this special field. The brilliant results that they achieved were accomplished because they were properly utilized and correctly fitted into the organi-

zation of medical service in the forward area. The keynote of the plan of medical care in advanced battle zones was that the sooner a wounded man received adequate first aid and subsequent surgical care, the better would be the outcome of his injuries. For this concept, much credit is due Colonel Churchill, theater consultant in surgery.

In short, everything that the surgeons of the 2d Auxiliary Surgical Group wrote in 1943 came to pass in the ensuing years of the war. The case fatality rate of chest wounds was sharply decreased, their postwar morbidity was even more sharply reduced, and thoracic cripples ceased to be seen.

Organization and Utilization of Auxiliary Surgical Group Teams

Although some specialty teams had been used during World War I (7), thoracic surgery did not then exist as a specialty and was therefore not represented among them. All of the teams operated independently and not as a group. The unit known as an auxiliary surgical group and utilized as surgical needs arose was employed for the first time in the U.S. Army in World War II.

Teams from the 3d Auxiliary Surgical Group supported the II Corps in North Africa and Sicily before the group was put under the control of the European theater. Some teams of the 5th Auxiliary Surgical Group also supported the Fifth U.S. Army. In November 1944, teams from the 1st Auxiliary Surgical Group attached to the Seventh U.S. Army included eight general surgical teams; two orthopedic surgical teams; two shock teams; and teams representing, respectively, thoracic surgery, neurosurgery, maxillofacial surgery, radiology, and dental prosthetic surgery. Later, other teams were added, including four general surgical teams; two thoracic surgical teams; and teams representing, respectively, orthopedic surgery, neurosurgery, and radiology.

Teams of the 2d Auxiliary Surgical Group served with the II Corps in North Africa and in Sicily, with the Fifth U.S. Army in Italy, and with the Seventh U.S. Army for the invasion of southern France and until the end of the war in Europe. In preparation for the invasion of southern France, half of the teams of this group, including two thoracic surgical teams, were attached to this Army and remained with it even after control of the Army passed to the European theater in December 1944. When this change was effected, fighting had slowed down considerably, and the loss of the teams was not immediately felt. When the character of combat changed from the battle of pursuit in July and August to the bitter fighting that characterized the North Apennines campaign in the fall and winter of 1944–45, the changed tactical situation produced the longest sustained combat load in the history of the Fifth U.S. Army. Surgical teams made up from base hospitals, valuable as they were, did not prove a substitute for the experienced teams that had been withdrawn.

The teams of the 2d Auxiliary Surgical Group cared for a total of 22,000 casualties during their service in the Mediterranean theater, of whom 1,364 had thoracic injuries and 903 thoracoabdominal injuries.[1, 2]

Early policies.—While some auxiliary surgical group teams were used in the North African campaign in 1942–43, thoracic surgical teams were not among them. Chest surgery was done entirely by the staffs of the forward hospitals and the general surgical teams, though some thoracic casualties from this campaign were later treated in the first thoracic surgery center established at Bizerte in July 1943.

There were a number of reasons for failure to use the chest teams at all, and to use the other teams properly, in this campaign. For one thing, the fighting was in eastern Algeria and later in Tunisia, while the headquarters of the 2d Auxiliary Surgical Group was in Rabat, Morocco. There was no clear concept in the minds of hospital staffs or in the headquarters of the theater surgeon of either the availability or the usefulness of these teams. The number of troops committed was small, at least as compared to the number committed in later campaigns, and the mobility of the front and the tenuous lines of communication furnished difficult problems of logistics.

Major Snyder's first special mission in North Africa, before he was appointed professional services officer to the Surgeon, II Corps, and later consultant in surgery to the Surgeon, Fifth U.S. Army, was to evaluate the work of the teams from the 2d Auxiliary Surgical Group that had been assigned to a British hospital in Algiers (*2*). He was immediately impressed with the potentialities and great usefulness of these teams in a combat zone, and it was on his recommendation, as already noted, that they were attached to field hospitals. They were used in this capacity in Sicily and throughout the remainder of the war. They were also attached to evacuation hospitals and, in some instances, worked in general hospitals and in general hospitals that served as chest centers.

Administrative considerations.—An auxiliary surgical group was composed of a headquarters and of a varying number of teams, including general surgical, thoracic surgical (thoracosurgical), orthopedic, maxillofacial, neurosurgical, and shock teams.

The coordination of functions and the employment of the teams of the 2d Auxiliary Surgical Group were effected through Group headquarters. The need for the use of the teams in special installations was worked out between the theater surgeon and Colonel Churchill, who, as consultant in surgery to the theater surgeon, participated in medical planning and was at all times fully aware of the tactical situation. When it was determined which field

[1] The work of the 2d Auxiliary Surgical Group is referred to frequently and in great detail throughout this volume for the reason that its records, which were carefully planned in advance, provide data on thoracic injuries not available from any other source.—F. B. B.

[2] To round out the picture, it might be mentioned that the 9th Evacuation Hospital, which was supporting the Seventh U.S. Army and was stationed in Naples from January to August 1944, was loaned to the French Army in the winter of 1944. It remained under the control of Maj. Gen. Morrison C. Stayer, Surgeon, Mediterranean theater.—F. B. B.

hospitals and which evacuation hospitals would be employed in a given operation, Colonel Churchill decided upon the number and kinds of teams to be employed, and the commanding officer of the group, Colonel Forsee, arranged for them to be properly deployed. In other words, these particular hospitals were augmented by surgical, thoracic surgical, and other specialty teams in anticipation of heavy casualty rates.

The number of teams attached to forward hospitals was flexible. During a slack period, two teams could handle all the work, but at least six surgical teams and two shock teams were required during an offensive, and the assignment of eight teams was not unusual. The hospitals that participated in amphibious landings required the assistance of teams from the group, and numerous teams were used during the Anzio operation, in which the Army had major forces in two areas separated by intervening territory held by the enemy.

Originally, auxiliary surgical group teams were not used to their full capacity. In Sicily and later in Italy, for instance, between 10 July 1943 and 1 February 1944, a thoracic surgical team cared for 100 casualties, of whom only 6 had penetrating wounds of the chest and of whom only 5 had thoracoabdominal wounds. This was a serious waste of trained personnel.

Another of the earlier policies which resulted in similar waste was the keeping of teams attached to field and evacuation hospitals with those installations even after their mission had been completed. In North Africa, in Sicily, and in the first months of the fighting in Italy, they were moved only when they were needed elsewhere. When the headquarters of the 2d Auxiliary Surgical Group was moved to Italy in 1944, these wasteful practices were discontinued, and thereafter, when the teams finished their special missions, they were recalled to headquarters at once for a period of rest and preparation for the next assignment.

All teams were kept on the alert, and were prepared to move to any assignment on very short notice. The Sicilian experience proved that attachment of these teams to field and evacuation hospitals resulted in a much higher grade of care for wounded casualties than the previous policy of surgery in clearing stations; the ability to shift the teams rapidly had much to do with the improvement.

Components of a thoracic surgical team.—All thoracic surgical teams were so constituted as to be complete operating units. Each team consisted of a thoracic surgeon (major), an assistant surgeon (captain), an anesthesiologist (first lieutenant), a surgical nurse, and two enlisted technicians. Each possessed special qualifications:

1. The thoracic surgeon was expected to have a precise knowledge of the surgical physiology of the chest, technical skill in thoracic surgery, and sound surgical judgment. It was also necessary that he have had a thorough training in general surgery as the basis for his training in thoracic surgery.

The latter requirement, which is highly desirable in civilian practice, proved essential in military surgery, when the exigencies of the military situa-

tion often made it necessary for the thoracic surgeon to work in the abdomen, and sometimes elsewhere in the body. The majority of patients admitted to field hospitals had multiple wounds because they had been injured by high explosive missiles, such as artillery shells, mortars, mines, and antipersonnel bombs. The general surgical training possessed by the thoracic surgeon (and the assistant surgeon) of a well-constituted thoracic surgical team fitted them for the assumption of responsibilities outside of their special field and greatly limited their usefulness if they could not assume them.

The thoracic surgeon was also responsible for preoperative preparation, determination of the optimum time for operation, postoperative care, and the designation of the time of evacuation for thoracic casualties.

It was always desirable to have a senior team chief act as senior officer for the teams in a hospital, and if the thoracic surgeon was senior to the other team chiefs, he had this responsibility also.

2. The assistant surgeon ideally had had a minimum of 2 years of surgical training and had devoted several months, at least, to the study of the medical aspects of thoracic diseases.

3. Since good anesthesia plays an important role in all chest surgery, the severity of the thoracic injuries sustained in World War II simply compounded this necessity. The anesthesiologist had to be capable of administering endotracheal and positive pressure anesthesia; of clearing the tracheobronchial tree of secretions by catheter suction or, if that was ineffective, by bronchoscopy; of recognizing and correcting disturbed cardiorespiratory physiology; and of directing the management of the shocked casualty. In addition to administering anesthetics, he had to share with the surgeon, the assistant surgeon, and the ward officer the responsibility for the preparation of casualties for operation and for their postoperative care.

4. The surgical nurse on a thoracic surgical team began by being a good surgical nurse. In addition, she had to have a detailed knowledge of the technical features of this specialty. She had to possess the temperament and adaptability to endure frequent operative ordeals during long periods of sustained tension. She also had to be an able instructor in operating room technique, capable of teaching the principles of asepsis and other techniques to corpsmen without previous medical experience.

5. The surgical technicians had to be good, well-disciplined soldiers, with a capacity and willingness for long, hard work. They were necessarily young, and they had to be in sound physical condition. They preferably possessed inquisitiveness concerning the accomplishments and potentialities of modern surgery. They had to be thoroughly reliable and responsible, since their duties included the preparation and sterilization of surgical supplies. They also had to be gentle and careful enough to serve as good assistants at the operating table.

6. All of the members of the team had to have sufficient physical stamina to endure long hours of taxing work at the operating table and also had to have a capacity for quick, decisive action.

Hospital Responsibilities

Field and evacuation hospitals.—In the field hospitals of the Fifth and Seventh U.S. Armies, auxiliary surgical group teams carried the chief responsibility of the professional service, while the organic personnel were chiefly responsible for administration. In evacuation and general hospitals, teams from the group augmented the regularly assigned surgical staff. No other arrangements would have been practical in these particular field hospitals, in which the assigned personnel were practically always numerically insufficient to handle both administrative and professional responsibilities.

In the early days of the war in North Africa, the teams were not always welcome. Organic personnel of both field and evacuation hospitals resented their presence and took the attitude that they could take care of their own responsibilities without outside help. Proper indoctrination of commanding officers of hospital installations and chiefs of service, and the careful placing of auxiliary surgical group teams in positions in which casualties were heavy and the need for help obvious, solved part of the difficulty. Quite as important was the performance of the teams themselves. Only second to their professional requirements was their ability to adapt themselves to varied and changing situations. Their own attitude and tact determined the reception they got from organic hospital staffs. Unless a spirit of cooperation existed on both sides, casualties suffered. Fortunately, when the usefulness of these teams was realized, cooperation was invariably excellent, and the original, quite natural, resentment over their assignment and assumption of responsibility quickly disappeared.

General hospitals.—Over a 2½-year period in the Mediterranean theater, three thoracic surgeons of the 2d Auxiliary Surgical Group (Major Burford, Major Brewer, and Major Samson) supervised eight major thoracic services in base section hospitals, five of which were at various times officially designated as chest centers.[3] The personnel of such a service might be permanent or might consist of a thoracic surgical team on temporary duty. The limited availability of thoracic surgeons and the need for their services in forward hospitals made it impossible to spare more than one team at a time to work in a general hospital, whether or not it served as a thoracic surgery center.

Records

The maintenance of accurate individual case records was a requirement for all teams. Enforcement of this policy made it possible for the 2d Auxiliary Surgical Group to compile the statistical and clinical data that serve as a point of departure for this history of thoracic surgery in World War II. Similar

[3] Major Samson later supervised the thoracic surgery service for 2 months at the 9th Evacuation Hospital in eastern France.

basic data (3,154 abdominal injuries) form the background for the extensive section on that subject in the second general surgery volume in this series (7).

Conclusions

The following comments were made in February 1945 by Colonel Forsee, commanding officer of the 2d Auxiliary Surgical Group, which was the first such group to function in World War II and which also had a longer experience than any other surgical group. His conclusions concern the thoracic surgical teams of the group, but for the most part, they are applicable to all teams:

1. The function of thoracic surgical teams, like that of all other surgical teams, is to augment the staff of hospitals throughout a theater when the requirements for surgery exceed the capacity of the regular staff. Teams of the 2d Auxiliary Surgical Group functioned in installations as far forward as divisional clearing stations, which was not an efficient mission, for these installations lack the facilities necessary for the proper care of first priority cases. They also functioned as far to the rear as general hospitals in the communications zone. They functioned in all varieties of hospitals in the Fifth and Seventh U.S. Armies and in the II Corps, in many hospitals in four different base sections, in British casualty clearing stations, and in British general hospitals. Teams of the group also supported the assault forces in amphibious operations.

2. A team assigned to a hospital should become an integral part of the staff during its temporary stay and should take its turn on the operating schedule with the intrinsic surgical staff.

3. The chief of the team should be responsible for preoperative and postoperative care, determination of when to operate, and designation of patients for evacuation when he considers them ready for transportation.

4. Teams should be relieved and returned to their own group headquarters as soon as the flow of casualties has so decreased that the organic hospital staff can care for them.

5. It is highly desirable that all teams function in as many types of hospitals as possible, so that they may be able to function efficiently on short notice in any of them.

6. During inactive or quiet periods at the front, surgeons should be attached individually to duty in base hospitals, to augment their experience.

7. The World War II policy of assigning to thoracic surgical teams the responsibility for the professional service in a chest center in a fixed hospital has proved highly successful. This plan permitted continuity of treatment of many patients who had received their initial wound surgery from other surgeons of the same auxiliary surgical group. A detailed followup of many problems of traumatic thoracic surgery was thus possible and permitted significant advances in this field.

8. The maintenance of accurate individual case records is a function of all teams.

DISPOSITION

Appraisal of the duty status of casualties recovered from chest wounds gained in accuracy with accrued experience. Clinical evaluation and psychologic estimates proved more valuable criteria in this appraisal than laboratory tests such as spirometry. Definite progress was made toward retaining more men for duty in the theater as the war progressed. Early in the war, almost every patient who underwent thoracotomy was evacuated to the United States, as was almost every patient with empyema. Later, it was possible to return significant numbers in both categories, especially the former, to duty in the theater. Furthermore, a great many of the patients who were returned to the Zone of Interior—some estimates were three of every four—were surgically well when they reached the United States. The principal reason for returning them was to evaluate their potential for military duty; this was necessary because of lack of previous experience with fully recovered patients with such severe injuries.

A large number of patients sent to the Zone of Interior were also evacuated because of associated wounds and not because of their thoracic status. Thus in 870 thoracic injuries analyzed by Major Burford and Maj. Edward F. Parker, MC, 379 of the patients were returned to the Zone of Interior, but only 86 (9.9 percent) of the number studied were evacuated because of their chest injuries and disability resulting from them.

Beyond these generalities, it is difficult to go. It was impossible to obtain adequate followup studies overseas. It is thought that perhaps from 40 to 45 percent of all patients with thoracic injuries could be kept on duty in the theater following hospitalization, but how many were later admitted to other hospitals because of symptoms and disability and how many of these were sent to the Zone of Interior remains unknown. It is unfortunate that prolonged observation was not possible during the war on a sufficiently large group of patients to warrant conclusions concerning the sequelae of intrathoracic wounds. It was these sequelae, actual or potential, which influenced ultimate disposition.

There were not many deaths in general hospitals and chest centers. Those which occurred were chiefly due to the complications for which the patients were under treatment.

The figures reported by Maj. (later Lt. Col.) William M. Tuttle, MC, and his associates from the thoracic surgery service at the 36th General Hospital, showed 2 deaths in 320 cases. Of the surviving 318 patients, 20 percent were returned to full duty and 33 percent to limited duty in the theater. The remainder were evacuated to the Zone of Interior. These statistics are typical of immediate results at other general hospitals and chest centers. That all of the soldiers who were returned to full or limited duty were able to maintain a duty status is in the highest degree doubtful.

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CHAPTER IV

Administrative and Basic Clinical Considerations in the European Theater of Operations

Dwight E. Harken, M.D.

Section I. Administrative Considerations

THE CONSULTANT SYSTEM

General Functions of Consultants

In the summer of 1942, a Professional Services Division was set up in the Office of the Chief Surgeon, Headquarters, ETOUSA (European Theater of Operations, U.S. Army), composed of senior consultants in most of the major medical and surgical specialties.[1] It is probably indicative of the still uncertain status of thoracic surgery at this time that a theater consultant in this specialty was not included in the list, although a consultant was appointed for such a specialty as plastic surgery, for instance, which was concerned with injuries that were far less potentially lethal.

After their appointment, these consultants originated all policies pertaining to specialized care and settled all problems referred to them concerning their specialties. Administratively, the activities of the senior consultants were limited to hospitals in the communications zone and the advanced section zone. Practically, their services were also fully utilized by surgeons of the armies. As a result, during the active campaign, there were seldom any difficulties in coordinating the professional services of hospitals in the rear and in the forward echelons.

In May 1943, 36 regional consultants were appointed in general surgery and the various specialties, and a number of additional medical officers were appointed to this position before a regional consultant in thoracic surgery was appointed in May 1944. In February 1944, base section consultants were appointed in general surgery and in medicine. Still later, regional consultants

[1] This has been a difficult chapter to prepare. There was no official consultant in thoracic surgery in the European theater. Col. (later Brig. Gen.) Elliott C. Cutler, MC, Chief Consultant in Surgery, ETOUSA, handled thoracic surgery himself during the organizational period, and his death soon after the war ended has made it impossible to supply numerous important details. We are grateful to Dr. (formerly Lt. Col.) Dwight E. Harken, who served as unofficial theater consultant, and later as regional consultant, in this specialty for collaborating in the preparation of this chapter and for supplying a large portion of the material for it.—F. B. B.

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in the various specialties were appointed on the Continent, though thoracic surgery was not included in the list.

Regional consultants who were appointed to centers for specialized care in appropriate hospital centers retained their own services in the hospitals to which they were attached. Tables of organization did not provide for these regional consultants, but by D-day, and in a number of instances long before, general hospitals had thoracic surgery sections. Difficulties arose in connection with rank. In the table of organization, the chief of the thoracic surgery section was a major. The problem was, when he served as regional consultant in his specialty, to make him a lieutenant colonel without taking the rank away from the head of some other section. Eventually, this was worked out, and when it was, it was routine for regional consultants to have the rank of lieutenant colonel.

The smoothness of operation and the brilliant success of the entire senior consultant and regional consultant system made it even more unfortunate that a consultant in thoracic surgery was not appointed when the system was set up in the Office of the Chief Surgeon, Headquarters, ETOUSA, and that none was appointed during the war.

Consultant Activities in Thoracic Surgery

During World War II, the responsibility for thoracic surgery, at least nominally, rested with Col. (later Brig. Gen.) Elliott C. Cutler, MC, Chief Consultant in Surgery to the Chief Surgeon, ETOUSA, Brig. Gen. (later Maj. Gen.) Paul R. Hawley. Colonel Cutler had always had a great interest in chest surgery though he was not a thoracic surgeon at heart in the modern sense of the term. In fact, when the Professional Services Division was first set up in General Hawley's Office, Colonel Cutler was convinced that thoracic surgery was not a true surgical specialty.

As time passed, his idea of supervising thoracic surgery himself seemed less practical. His associations with British surgeons who had had a wide experience in it, and his own observations on these injuries, gradually modified his point of view, and, by the end of the war, both he and General Hawley were prepared to accept thoracic surgery as an important surgical specialty.

In December 1943, in a comment in his official diary on his recent visit to Italy, Colonel Cutler listed the admirable management of thoracic and thoracoabdominal wounds that he had observed in the hospitals of the North African (later Mediterranean) theater as the chief surgical advance in the theater. He noted several points of importance: the fact that the chest wall rather than the lung was the most frequent source of hemorrhage in thoracic wounds; the consequent emphasis on adequate debridement of the parietal wound, with effective hemostasis; the minimal need for pulmonary surgery; the prevention of empyema by early, repeated thoracentesis; the importance of roentgenologic control in all thoracic injuries; and the frequency and seriousness of thoracoabdominal injuries.

On 24 January 1944, Colonel Cutler wrote to Col. James C. Kimbrough, MC, Chief, Professional Services Division, Office of the Chief Surgeon, Headquarters, ETOUSA, that for some time he had been having considerable difficulty in his assumption of personal responsibility for the proper care of thoracic surgery in the theater. He had done a great deal of the supervisory work himself, particularly in the training of medical officers in this specialty; the training was necessary because very few surgeons had come to the theater qualified to do chest surgery. The caseload had now become so large that it demanded the attention of a properly qualified consultant who could assist him in controlling the work and in standardizing procedures and routines. The work, of course, could be expected to become very much heavier after the invasion of the Continent.

Colonel Cutler did not ask that the consultant whom he was requesting be on the table of organization at the theater chief surgeon's headquarters. In fact, he believed that it would be more efficient for him to carry on his work from a general hospital.

Colonel Cutler's recommendation for consultant in thoracic surgery was Maj. H. Brodie Stephens, MC, who was then attached to the 30th General Hospital, near Mansfield, Nottinghamshire. He regarded Major Stephens as fully qualified for the position, and he believed that his seniority and other qualifications would make him generally acceptable to other surgeons who would work under him.

On 4 February, Colonel Cutler wrote to Major Stephens to tell him that he had made the official request that he be appointed senior consultant in thoracic surgery in the European theater but that General Hawley did not wish to make any more official appointments in the consultant group. He was quite willing, however, that Colonel Cutler should use Major Stephens unofficially.

In the meantime, Capt. (later Lt. Col.) Dwight E. Harken, MC, had arrived in the theater, in the fall of 1943, with the 1st Auxiliary Surgical Group. His interest in thoracic surgery, plus the fact that he had done work with the British group of thoracic surgeons and had served as resident under Mr. A. Tudor Edwards, F.R.C.S. (fig. 11), at the Brompton Hospital in London, admirably fitted him to act as liaison officer with the British and as Colonel Cutler's representative in thoracic surgery. In particular, he did the active work in the courses on thoracic surgery given in British hospitals under Mr. Tudor Edwards' supervision. In May 1944, when the 160th General Hospital was established as a thoracic surgery center in the 15th Hospital Center, Cirencester, Gloucestershire, Major Harken was appointed chief of the thoracic surgery section and regional consultant in thoracic surgery. Also, although he was never officially appointed to the position, he served as theater consultant in thoracic surgery under Colonel Cutler.

In fulfillment of his consultant functions, Captain Harken:

1. Did the active teaching in the courses in thoracic surgery for selected U.S. medical officers at British hospitals (p. 120).

FIGURE 11.—Mr. A. Tudor Edwards, 1941–45, civilian consultant in thoracic surgery for the British Emergency Medical Service, British Army, and Royal Air Corps; Surgeon-in-Charge, Department of Thoracic Surgery, London Hospital; Surgeon, Brompton Hospital for Diseases of the Chest; Consultant Advisor to Minister of Health for Chest Casualties; and Consulting Surgeon, King Edward VII Sanatorium, Midhurst.

2. Reviewed the experience of the principal British thoracic centers in their care of chest injuries from a vast number of air-raid casualties. The surgical policies and practices set up for U.S. Army thoracic surgeons were derived from the aggregate of the British experience.

3. Wrote a large part of the original draft of the thoracic surgery section in the "Manual of Therapy, European Theater of Operations" (p. 141).

4. Wrote the original draft of the standing operating procedure that governed policies in thoracic surgery in the European theater after D-day (p. 138).

5. Briefed all U.S. hospitals in the United Kingdom before D-day on the management of chest injuries.

When Colonel Cutler wrote to Major Stephens to tell him that he had been unable to secure General Hawley's permission for his appointment as consultant in thoracic surgery but had his permission to use him unofficially, he explained Captain Harken's activities and said that, under these new circum-

stances, they would be improper without Major Stephens' sanction. He therefore directed Major Stephens to get in touch with Captain Harken, so that together they could set up general principles and policies in the field of thoracic surgery. On 9 March, Major Stephens wrote Colonel Cutler that Captain Harken had visited the 30th General Hospital the preceding week, where he had made an excellent talk on thoracic injuries. Captain Harken had also provided him with slides for use in the talk he himself was scheduled to make on the same subject at the Eastern Base Section meeting on 24 March.

Major Stephens expressed himself as anxious to have a conference with Colonel Cutler, to obtain his general views on thoracic surgery, so that he could incorporate them in this talk and in other instructions. So far as is known, nothing further came of Major Stephens' proposed activities as consultant.

Recommendations for the U.S. Army of Occupation

From time to time after the war ended, Colonel Cutler, in response to requests from the theater chief surgeon's office, made recommendations for the organization of professional services in the U.S. Army of Occupation. A system of hospital centers was planned for the administration of the farflung network of hospitals that would be required for the occupation forces. The prevailing system of regional consultants was to be continued; that is, qualified medical officers were to be appointed to serve in this role for their own hospitals and the surrounding hospitals. The system developed in the European theater of appointing medical officers as surgical coordinators, to coordinate all surgical activities within the various hospital centers, was also to be continued.

All of these concepts were agreed to in principle. The consultant system put into effect in July 1945 did not, however, include a consultant in thoracic surgery in the Paris hospitals, for which consultants in other specialties were appointed at once. Nor was a consultant in thoracic surgery appointed in the Office of the Chief Surgeon, Communications Zone, Headquarters, ETOUSA, which was to move later to Headquarters, USFET (U.S. Forces, European Theater) in Frankfurt. In other words, in spite of the importance of this specialty, no theater consultant in thoracic surgery ever served officially in the European theater in World War II.

PERSONNEL

Thoracic Surgery

The number of trained thoracic surgeons in the European theater was always small. In September 1943, there were only 12 surgeons in the United Kingdom Base considered capable of handling thoracic surgery in a general hospital and only 8 considered capable of handling it in a station hospital.

These shortages had to be made up in the best fashion possible, which was to assign the small number of qualified and experienced surgeons to head chest centers and thoracic surgery sections. The shortages could not be overcome by the use of surgeons who had had 3 or 4 months' training in thoracic surgery after they had entered the Army. These officers proved extremely useful on thoracic surgery services, but they were not qualified to assume full responsibilities for them.

The situation was made more difficult than it should have been by administrative obstacles. By October 1944, it had been realized that special hospitals for thoracic surgery and other specialties would be necessary. There was still, however, no provision for a single thoracic (or plastic) surgeon in any medical installation in the communications zone. Constant difficulty was therefore encountered in fitting thoracic surgeons into the inflexible tables of organization for general and station hospitals and in providing the additional assistance necessary to run a thoracic service efficiently. It was just as important that thoracic sections operate efficiently as it was that neurosurgical services should, yet neurosurgeons were provided for in tables of organization for general and station hospitals long before either thoracic or plastic surgeons were provided.

Because of table-of-organization difficulties, it was frequently necessary to assign thoracic surgeons to such positions as chief of the surgical service, chief of aseptic surgery, or even ward officer. These were not satisfactory circumventions, and they had the added disadvantage that, once such an assignment was made, it was very difficult to change it. Colonel Cutler commented in his official diary that emergency changes of assignment could sometimes be handled quickly, but that routine changes often occupied weeks and were sometimes not accomplished at all.

In the meantime, the list of thoracic surgeons in the theater was sent to Colonel Cutler by Captain Harken, and he sent the names, in turn, to Colonel Kimbrough and General Hawley for action. Personnel difficulties continued until the end of the war, but in October 1944, after a round of visits of inspection to hospitals in the United Kingdom Base, Colonel Cutler expressed the opinion that this section had four "superlatively good" thoracic surgeons: Lt. Col. (later Col.) Laurence Miscall, MC, at the 137th General Hospital, located near Ellesmere, Shropshire; Lt. Col. George N. J. Sommers, Jr., MC, at the 140th General Hospital, near Blandford Forum, Dorsetshire; Lt. Col. (later Col.) Arthur S. W. Touroff, MC, at the 155th General Hospital, Malvern Wells; and Major Harken at the 160th General Hospital. In Colonel Cutler's opinion, this base section was now adequately covered from the point of view of thoracic surgery, in which he said that more advances had been made during the war than in any other surgical specialty.

It was the general opinion that, in the future, the personnel of a thoracic section should be made up of a team composed of a lieutenant colonel as chief of section; a captain as anesthesiologist; two captains to serve as surgical assistants and also as ward officers; three surgical nurses, one of whom would be a

first lieutenant; and three surgical technicians, grade 4. These groups should either be sent overseas from the Zone of Interior as table-of-organization cellular units or should be assigned by the Professional Services Division, Office of The Surgeon General. Obviously, personnel for such groups must be selected with great care.

Anesthesia

Anesthesia for chest surgery was never a problem in the European theater. Expert anesthesiologists were available all the way from field hospitals near the frontlines to general hospitals in the base area. They had at their disposal a wide variety of anesthetic agents and could use intravenous, inhalation, or regional techniques according to the requirements of the individual patient. When differential pressure was needed for intrathoracic surgery, endotracheal anesthesia was always used, with safety for the patient and satisfaction for the surgeon.

At a meeting of the theater consultants in December 1944, Lt. Col. (later Col.) Ralph M. Tovell, MC, presented an analysis which he had prepared for the theater chief surgeon on the use, according to medical echelon, of inhalation, regional, and local anesthesia. At the conclusion of the presentation, General Hawley paid tribute to the quality of the work done by anesthesiologists in the theater, under Colonel Tovell's supervision. "The fine surgical results that have been gained in this theater," he said, "are in no small way the responsibility of Colonel Tovell for the fine service that he has brought here."

In a conference with Third U.S. Army surgeons, also in December 1944, Colonel Cutler noted in his official diary that he found very gratifying the remarks made by Col. Joseph A. Crisler, Jr., MC, Consultant in Surgery, First U.S. Army, that "one of the greatest boons to surgeons in medical facilities of the field army were the anesthetists supplied by Colonel Tovell * * *. This may be taken as almost a personal triumph for Colonel Tovell, who has worked indefatigably in his special field and now is reaping a rich and well-deserved harvest."

TRAINING

Training in British Hospitals

Late in 1942, Mr. Tudor Edwards, who was then serving as civilian consultant in thoracic surgery for the British Emergency Medical Service (p. 115) gave a course in thoracic surgery, which consisted of lectures and demonstrations in a number of hospitals, for U.S. Army medical officers. It was a most valuable introduction to combat surgery.

When Mr. Tudor Edwards was asked to repeat the course in 1943, he felt obliged to decline. This was entirely reasonable, for his own work as consultant for the Emergency Medical Service, as well as for the British Army and the Royal Air Corps, constituted an incredible burden for a man who had already had several coronary thromboses.

Mr. Tudor Edwards' course had been so valuable, however, that Colonel Cutler could not accept his refusal as final. He therefore suggested to him that he might find it possible to lend his name and general supervision to the course if U.S. Army medical officers carried the bulk of the burden. Mr. Tudor Edwards replied that this was not practical: American medical officers, he said, would not be permitted to move freely about British hospitals, nor did they know the British hospitals and British ways well enough to make the proposed arrangement workable. In his opinion, friction would be inevitable.

As an afterthought, Mr. Tudor Edwards asked Colonel Cutler what American officer he had had in mind to supervise the courses. Colonel Cutler replied that he was considering Captain Harken. Mr. Tudor Edwards said that this appointment would be entirely acceptable to him, and he then withdrew all of his objections to the courses in British hospitals, but, he said, "Harken is not your man, he's mine. He was my resident at the Brompton Hospital before the war, and he knows us well enough to do the job."

Circular Letter No. 174, issued on 28 November 1943 (*1*), called attention in paragraph 4g to the 2-week courses in thoracic surgery to be conducted at several British thoracic surgery centers in the London area under Mr. Tudor Edwards. It was intended for thoracic surgeons or for medical officers with some previous training in thoracic surgery.

There were seven of these 2-week sessions. Each consisted of lectures and demonstrations by the most eminent thoracic surgeons in England. Between 8 and 10 U.S. medical officers participated actively in each course, and visitors who attended the sessions but did not actively participate brought the number in each course to about 15. Major Harken served as director and coordinator of all of the courses. The slides used in the lectures and demonstrations represented probably the most complete collection of roentgenograms of chest trauma ever collected.

The formal courses just described had three objects:

1. To permit the officers in attendance to learn as much as possible about the thoracic surgery of combat-incurred wounds, including both principles and practices.

2. To give medical officers interested in thoracic surgery an opportunity to become acquainted with the best British chest surgeons and internists. This was an unparalleled opportunity, for all of these British physicians and surgeons were highly skilled men, with broad visions and horizons.

3. To provide useful occupation for men bored to death with inactivity in tents and nissen huts and physically uncomfortable in the frightful British winter weather. These courses provided a brief respite for them in warm, dry, metropolitan surroundings and a little exposure to the more pleasant life in London.

In addition to the formal courses just described, selected Medical Corps officers were able to observe the work of British chest surgeons in chest centers in the areas in which their units were stationed.

Other Training

In addition to the specialized training in British hospitals just described, the following training was given to medical units in the United Kingdom Base:

1. Medical Corps officers who went to North Africa in November 1942 received special instruction at Tidworth Barracks, 16–18 September. Colonel Cutler's lectures on surgical subjects included the management of sucking wounds and other thoracic injuries.

2. The Medical Field Service School was established at Shrivenham Barracks, Swindon, England, by Circular No. 22, on 23 February 1943 (*2*). The first courses were given on 8 March 1943, with Capt. (later Lt. Col.) Bernard J. Pisani, MC, as director. There were some initial difficulties, including the appointment of instructors without consultation with, and approval by, the Professional Services Division, Office of the Chief Surgeon, Headquarters, ETOUSA. In a short time, however, this school became a highly efficient functional unit. The lectures and conferences on problems in combat surgery and acute medical and neuropsychiatric conditions did not include special instruction in thoracic surgery, though chest wounds, of course, were discussed in the surgical lectures.

3. All medical units which reached the United Kingdom before D-day received a minimum of 3 hours of lectures on thoracic injuries. The content of these briefings, most of which were given by Captain Harken, was decided upon in a conference with Colonel Cutler on 27 October 1943. The policies and practices recommended were based on the experience in the North African theater to date and on an analysis of 300 British air-raid casualties in the London area. All medical and surgical problems that conceivably might arise in chest injuries were thoroughly discussed.

4. Professional training of officer personnel also included lectures by both military and civilian authorities whenever units were so situated that this was practical. These lectures were supplemented by weekly grand teaching rounds, at which problems of disposition as well as medical care were discussed.

5. Nurses received continuous training in compliance with section II, Training Memorandum No. 3, issued on 15 February 1943 (*3*). Thoracic surgery and penicillin therapy were covered in the training.

6. The availability of basic and current medical literature formed an important background for practical training, and Colonel Cutler therefore maintained a constant interest in hospital libraries. Originally, the medical texts and journals sent from the Zone of Interior had simply been held in supply depots and not distributed. He ended this situation promptly and also ended the foolish mutilation of U.S. medical journals by censors in the Zone of Interior before they were shipped to England.

Anesthesia

After some initial resistance to all formal training overseas, special courses in anesthesia were given in a number of hospitals to medical officers, with spe-

cial emphasis on endotracheal anesthesia and positive pressure techniques for thoracic surgery.

Special courses for nurses were also given in some hospitals. As soon as the 160th General Hospital arrived in England in April 1944, daily lectures on anesthesia were given to 12 nurses, all volunteers for the course. Four were selected for further specialized training. This course was concluded on 3 June 1944, and on 12 June, the hospital received its first battle casualties.

In March 1944, a 3-month course of instruction in the fundamentals of general anesthesia was given at the 15th General Hospital, Ellesmere, Shropshire, to two medical officers and four nurses. It consisted of didactic lectures, demonstrations, and practical training. A small group of technicians were also trained in anesthesia and used as a reserve when casualties were heavy.

In the spring of 1944, two courses in anesthesia, each lasting a month, were given to four officers and seven nurses from the 12th Field Hospital and the 122d, 123d, 124th, and 134th Evacuation Hospitals. Mimeographed outlines, training films, and practical instruction were employed. The practical instruction included intravenous, inhalation, and endotracheal techniques.

By special arrangement with the Office of the Chief Surgeon, Headquarters, ETOUSA, a 4-day course in anesthesia for medical officers and nurses was conducted at the 10th Station Hospital in the Manchester area. This course was designed to precede a 30-day period of temporary duty in this specialty at station and general hospitals.

DISSEMINATION OF INFORMATION

Medicomilitary medicine requires a degree of uniformity in both policies and practices that is not necessary in civilian practice (p. 187). Without such uniformity, with so many medical officers of such varied training and experience working in medical installations in many different military echelons, chaos could have resulted.

In the European theater, uniformity in thoracic surgical practices was more difficult to achieve, in the absence of a theater consultant in this specialty, than it might have been otherwise. It was accomplished in the following ways:

1. Approved procedures in all types of wounds, based on the results of research, civilian experience, and experience in the Mediterranean theater, were set forth in circular letters and other directives issued by the Office of the Chief Surgeon, Headquarters, ETOUSA. These letters were later altered as necessary in the light of the post-D-day experience in the European theater.
2. A medical bulletin, containing similar material, was issued monthly.
3. Shortly before D-day, a manual of therapy was published and distributed to every medical officer in the theater (p. 141). This manual outlined official procedures in combat-incurred wounds in forward installations. The manual was authoritative, since it had been compiled by the senior consultants

in surgery and the surgical specialties in the Office of the Chief Surgeon, Headquarters, ETOUSA. Later, it was modified and supplemented as necessary in the light of combat experience in the theater. The material on thoracic injuries was a somewhat oversimplified outline of material prepared by Major Harken.

4. The senior consultant group in the Office of the Chief Surgeon, Headquarters, ETOUSA, met frequently with the regional consultants in the specialties and also with their British, French, and other colleagues to discuss their joint experiences. From the overall picture, they were able to evaluate the results of treatment and suggest improvements in methods. These improvements were incorporated in circular letters, which were so widely distributed that all medical officers in the theater could keep in touch with the latest and best techniques of military practice. The letters, Colonel Cutler noted in his official diary, make up a story which might well be entitled "Surgery in the European Theater in World War II."

A great deal of information on thoracic surgery was disseminated by Colonel Cutler himself as he moved about the theater. He made it his business to keep himself informed on thoracic surgery by frequent conferences and conversations with the chest surgeons in the hospitals he visited. He was an inspiring man and was able to get the best out of all who worked with him. The information thus secured he synthesized into useful policies. He was not, as already mentioned, a chest surgeon in the modern sense of the term, but he was a vastly experienced general surgeon, with good common sense, who was willing to ask for advice and to take it. After he himself had had what seemed to him a good idea, he would often write to the thoracic surgeons in the theater and ask for their comments before issuing it as a directive. He leaned heavily for advice on Mr. Tudor Edwards, whom he always referred to as "the great man."

These policies of Colonel Cutler's proved particularly useful after D-day. He made it his business to gather professional comment from the surgical specialists who had cared for the casualties in the first days of the invasion of the Continent, and this information, based on combat experience, often under fire, was incorporated in Circular Letter No. 101 issued from the Office of the Chief Surgeon on 30 July 1944 (*4*).

5. In addition to the informal conferences just described, a number of formal professional meetings were held.

Circular Letters

Circular letters issued from the Office of the Chief Surgeon contained the following information pertinent to chest wounds:

1. Circular Letter No. 71, 15 May 1944 (*5*), concerned the general management of battle casualties. Casualties with chest wounds who were to be considered nontransportable and cared for in field hospitals were listed as

those with thoracoabdominal wounds, thoracic wounds that were serious either because they were large and sucking or because they were associated with intrathoracic hemorrhage, and thoracic wounds of any type associated with shock that did not respond to appropriate therapy. The difficulty of diagnosing thoracoabdominal wounds was noted, and medical officers were reminded that a missile that entered via the buttocks might lodge in the thorax, while a missile that entered by way of the shoulder might produce a thoracoabdominal wound. Roentgenologic examination would clarify the situation, but if facilities for it were not available, the medical officer must be certain to examine the body cavity opposite from the point of wounding.

Many of the general directions in this circular letter were applicable to chest wounds as to all other wounds. Thus it was pointed out that infection arising from contamination caused by repeated inspections and changes of dressing might delay or prevent delayed primary wound closure after the casualty had arrived at a third echelon unit. It was also noted that one of the best safeguards a patient could have was an adequate and legible record, which would make it possible for a receiving officer farther to the rear to refer to the record rather than look at the wound.

2. Circular Letter No. 80, issued on 10 June 1944 (*6*), also included a general discussion of battle casualties. It mentioned hospitals for the care of special types of wounds, including thoracic surgery, and recommended that in these hospitals separate sections be maintained for each specialty and that the heads of these sections be used as regional consultants.

3. Circular Letter No. 101, issued on 30 July 1944 (*4*), supplemented the "Manual of Therapy, European Theater of Operations," issued on 5 May 1944 (*7*), and the circular letters already issued. Its contents, as already mentioned, were based on the experience acquired during the first 5 weeks of active operation after D-day.

4. Circular Letter No. 23, issued on 17 March 1945 (*8*), contained a section devoted to thoracic wounds, including resuscitation, sucking wounds, hemothorax, empyema, intercostal nerve block, thoracotomy, and thoracoabdominal wounds.

Professional Meetings

Inter-Allied Conferences on War Medicine.—On 27 October 1942, Colonel Cutler met, for the first time, at the Royal Society of Medicine, with representatives of the medical services of all the Allied countries to plan what came to be the Inter-Allied Conferences on War Medicine. The first monthly meeting was held on 7 December 1942. The presentations made at these meetings were published at the end of the war (*9*); there was a continuous improvement in them as the war progressed.

The subject of thoracic surgery occupied many of the meetings. In November 1943, the conference met with Captain Harken, then with the 1st Auxiliary Surgical Group. At the conference held in January 1945, Mr. Tudor

Edwards, in his role of honorary consulting thoracic surgeon to the British Army, presented an extensive discussion of thoracic surgery in the field and at the base, with particular attention to surgery at the base. His remarks were based on 1,683 thoracic casualties admitted to chest centers in the United Kingdom between D-day and 30 September 1944.

At the same meeting Mr. T. Holmes Sellors, Regional Adviser in Thoracic Surgery, British Emergency Medical Service, also discussed chest surgery at the base. Lt. Col. Charles S. Welch, MC, presented an analysis of 380 thoracic injuries observed during the first 6 months of fighting on the Continent.

Army Medical Society, European Theater of Operations.—On 14 May 1943, the organizational meeting of the Army Medical Society, ETOUSA, was held with Maj. (later Col.) Robert M. Zollinger, MC, in charge. The first formal meeting was held on 23 June 1943, at the 298th General Hospital, Bristol. Monthly meetings were held thereafter at different hospitals until the pressure of combat activities brought an end to them in August 1944.

Other professional meetings.—On 14 and 15 April 1943, Colonel Cutler attended the meeting of the Association of Thoracic Surgeons of Great Britain and Ireland, of which Mr. Tudor Edwards was president.

The first discussion at the Inter-Allied Consultants Conference in Brussels on 10 October 1944 concerned chest injuries. Maj. J. Leigh Collis, RAMC, stated that infection was of major importance in them. This observation came as a surprise to Colonel Cutler, since Major Harken had recently reported to him from the 160th General Hospital thoracic surgery center that empyema was not a major problem in these injuries. Col. G. A. G. Mitchell, RAMC, who opened the discussion on penicillin, stated that the British considered that a satisfactory bacteriostatic level could be maintained by the intramuscular injection of 100,000 units in physiologic salt solution each 24 hours. Major Collis thought penicillin of little value unless it was instilled in the pleural space.

At the third Anglo-American Consultants Conference held in Paris on 25–26 May 1945, the vigorous discussions conducted on thoracic surgery included anesthesia for chest operations. There was active participation by both British and U.S. medical officers.

Colonel Cutler seized the opportunity offered by the Trench Foot Conference held in Paris in January 1945 to work over the current circular letters dealing with the treatment of battle casualties. Chest surgery was extensively discussed.

The information gained at all of these meetings was transmitted by Colonel Cutler and other consultants to all medical officers in the theater by the various channels already described.

The experience of Major Harken and his associates at the 160th General Hospital thoracic surgery center was presented to the Royal Society of Medicine and the Royal College of Surgeons in January and April 1945, respectively.

SUPPLY AND EQUIPMENT

Early Deficiencies

Hospitals which reached the United Kingdom in 1942 and some of those which supported the North African invasion in November of that year were poorly equipped from the standpoint of thoracic surgery (p. 84). The chest surgeons, in fact, looked with envy upon the ample equipment of excellent quality possessed by their British counterparts.

When Colonel Cutler inspected the thoracic surgery equipment in November 1942, he described it as completely outmoded and of "20-years-past" vintage. He thought most of what was on hand was close to useless. The medical chests to be used under battle conditions were totally inadequate. So were the instrument kits. There were no morphine syrettes for forward work. There was no sulfonamide powder for wounds (at this time, local chemotherapy was still advocated). There was no provision for local or intravenous anesthesia. The necessary needles and silkworm gut sutures for emergency closure of sucking chest wounds were not on hand, though this was a simple, lifesaving procedure, which almost anyone could carry out.

It was possible to supply most of these deficiencies from British sources, and Colonel Cutler took immediate steps to see that this was done. Meantime, when equipment was in short supply or totally lacking, ingenious improvisations were employed.

As in the Mediterranean theater, X-ray films were in somewhat limited supply in 1942 and early 1943, and some restrictions upon their use were necessary.

Later Provision

By the time of the invasion of the Continent, all of these initial shortages and deficiences had long since been overcome. All equipment was now in full supply and of the best quality. Temporary shortages, of course, still occasionally occurred, chiefly because of transportation difficulties. This usually happened when fighting was intense and the situation critical, as in the area of the Battle of the Bulge.

Nonstandard equipment was procurable as necessary, but not all that was requested was supplied because not all of what was requested was considered necessary. As in the Mediterranean theater, chest surgeons, like all other medical officers fresh from civilian life, soon learned to do excellent surgery with no more than the generally excellent equipment provided in tables of equipment.

The following experience indicates how rapidly special equipment that was really needed could be supplied: On 22 March 1944, Major Harken wrote Colonel Cutler that the U.S. experience to date, as well as the British combat experience, had proved conclusively that the essential treatment of hemothorax

was complete and early aspiration; and that the mortality, morbidity, possible deformity, and future pulmonary function were all favorably influenced when this technique was used. At this time, the proper equipment for its employment was not available to U.S. medical officers in the United Kingdom.

Major Harken therefore requested that immediate steps be taken to provide all medical units with standard record syringes equipped with 2-way stopcocks and 15-gage aspirating needles. There was no acceptable substitute for this item. In view of the importance of the correct treatment of hemothorax, Major Harken suggested that a sufficiently large order be placed to permit automatic distribution of four of these syringes to each hospital in the theater.

The day this request was received, Colonel Cutler forwarded it, with his approval to the Supply Division, Office of the Chief Surgeon, Headquarters, ETOUSA. He not only recommended that the syringes, in the quantity requested, be distributed to all hospitals in the European theater, both Army and SOS (Services of Supply), but also recommended that they be added to the tables of equipment of all hospitals arriving in the theater. The recommendation was promptly implemented.

Some equipment was considerably improved as time passed. Thus the mounting of the field type of anesthetic machine upon a wheeled cart that also carried the large gas tanks resulted in both increased mobility of the apparatus and increased economy of operation.

Auxiliary Surgical Group Teams

Equipment for auxiliary surgical group thoracic surgical teams was always excellent. Some teams in the European theater carried accessory surgical equipment in special surgical trucks or personnel carriers, but most teams had only a single basic instrument set, which was adequate for two major thoracic procedures, and an anesthetic machine.

It was the general policy to pool the tentage and transportation for all teams, to assure economy in their use. Personal equipment for the medical officers on the teams consisted of standard Army field equipment, including a sleeping bag and an air mattress.

Thoracic Surgery Centers

Thoracic surgery centers often required specialized equipment. If it was available from Army medical depots or from British sources, usually civilian sources, it was supplied at once. The officer with ingenuity and aggressiveness was always able to get it if it existed in the European theater. When the equipment had to be brought into the theater from the Zone of Interior, supply lines were remarkably efficient.

The basic equipment of chest centers was both excellent and abundant. It was recognized that the chest surgeons working in them were performing special procedures, some of which, such as decortication, were new operations. Every attempt, therefore, was made to supply such nonstandard equipment as these chest surgeons needed for their purposes.

Supplies of Penicillin and Blood

The first shipment of penicillin to the United Kingdom, consisting of 180 boxes, was received in the theater on 5 May 1943. Each box contained 10 ampules, and each ampule contained 10,000 Florey units. This first shipment thus consisted of 18,000,000 units. The initial use of penicillin was necessarily restricted, but long before the invasion of the Continent, full supplies were available, and antibiotic therapy was possible whenever it was indicated.

The story of the supply of blood for the invasion of the Continent and the later supply of this agent is told in full in the volume in this series of histories that deals with the blood program in World War II (*10*). After the first shortages on the Continent after D-day, when, for a time, blood had to be rationed and used only for casualties whose need for it was critical, it was in ample supply because of the daily airlift from the Zone of Interior. When possible, however, especially for casualties who required multiple transfusions, thoracic surgeons preferred to use blood from the blood bank in the United Kingdom. This was because blood flown from the United States was preserved in Alsever's solution and the excess of fluid was undesirable in casualties with chest injuries. They were highly susceptible to pulmonary edema, and the policy was to limit replacement therapy to as small quantities of fluid (electrolytes) as were adequate (p. 253).

THORACIC SURGICAL TEAMS

The concept of the specialty surgical team was in Colonel Cutler's mind as early as the invasion of North Africa. On 6 January 1943, he recommended to the theater chief surgeon that surgical teams in various specialties, including thoracic surgery, should be appointed to serve in forward elements of the division, in order to make observations on special types of wounds from the battlefield to the evacuation hospital. The investigation of even 50 cases of each type of wound, he thought, would open a new outlook on their management and prognosis. If such teams were appointed, he wrote General Hawley, Col. Johan C. Holst, consultant in surgery to the Norwegian Forces in the United Kingdom, who was an experienced thoracic surgeon, had expressed the desire to accompany the thoracic surgical group.

A number of special studies of chest injuries were made in the European theater but none under the precise circumstances envisaged by Colonel Cutler. His concept of surgical teams in the various specialties was implemented in the teams of the auxiliary surgical groups that had just been organized.

Auxiliary Surgical Groups

There is general agreement that the reason that thoracic and thoracoabdominal injuries carried a much lower mortality in World War II than in World War I was due in large part, at least in the Mediterranean and European theaters, to the effective work of the thoracic surgical teams of auxiliary surgical groups.

In the European theater, as in the Mediterranean (p. 105), these teams worked chiefly in field and evacuation hospitals. In the European theater, however, the groups were assigned to the Army surgeon, in contrast to the Mediterranean policy, by which the teams were controlled at theater level. In the European theater, as in the Mediterranean, the effectiveness of all group teams depended to a considerable degree upon how they were received and utilized in the installations to which they were assigned. After the first—quite natural—surprise, not unmixed with resentment, at the presence of these teams in field and evacuation hospitals and at the heavy responsibilities assigned to them, their potentialities were realized, and they were fully utilized by the desire and cooperation of most commanding officers.

In addition to the care of chest casualties, the teams served usefully in the indoctrination of other members of the medical staff, as well as of the nursing staff and technicians, in the principles of management of chest injuries.

In all pre-D-day discussions, Colonel Cutler emphasized that the experience of the Mediterranean theater showed that thoracic surgical teams must be able, whenever necessary, to handle other injuries, particularly abdominal injuries. Thoracic surgical teams capable of doing only thoracic surgery would be useful in base areas, where complete segregation of injuries was possible. In the circumstances that prevailed in forward areas, team surgeons must be able to handle other wounds also, and this consideration was always borne in mind when assignments were made.

Special Experiences

The following data on the experiences of the four auxiliary surgical groups that supported U.S. Armies in the European theater give some indication of the enormous number of thoracic and thoracoabdominal injuries that the teams handled:

1st Auxiliary Surgical Group.—The 1st Auxiliary Surgical Group supplied teams to the 3d Auxiliary Surgical Group after D-day; these teams remained under the control of the latter group during most of the campaigns in Europe. Other teams from this auxiliary surgical group served with the Seventh U.S. Army, in November 1944; with the XVIII Corps (Airborne), during Operation MARKET; and with the 17th Airborne Division, during the cross-Rhine operation. The group came under the control of the Fifteenth U.S. Army on 18 April 1945.

Its work for 1944 was not tabulated. In 1945, its teams handled 701 thoracic injuries and 332 thoracoabdominal injuries.

2d Auxiliary Surgical Group.—The 2d Auxiliary Surgical Group, which had the longest experience of any of these groups, served in North Africa and Sicily with the II Corps; with the Fifth U.S. Army in Italy; and with the Seventh U.S. Army in southern France and during the remainder of the fighting in Europe, after the Seventh U.S. Army passed from Mediterranean to European theater control in December 1944.

The teams of this group handled approximately 22,000 casualties. During 1944 and 1945, they cared for 1,364 thoracic wounds and 903 thoracoabdominal wounds. These data are discussed in detail elsewhere (vol. II, appendix).

3d Auxiliary Surgical Group.—Teams from the 3d Auxiliary Surgical Group supported the II Corps in North Africa and Sicily and the First U.S. Army in France, Belgium, and Germany.

Its detailed data are not complete, but it is estimated that its personnel cared for a total of 25,000 casualties in both theaters. Complete information is available on 18,885 injuries handled in the European theater, including 2,018 thoracic wounds and 824 thoracoabdominal wounds. It was also estimated by the team surgeons that combined thoracic, thoracoabdominal, and abdominal wounds accounted for 61 percent of the work in field hospitals; 18 percent of the work in modified field hospitals; 30 percent of the work in beach clearing stations; and 10 percent of the work in evacuation hospitals.

4th Auxiliary Surgical Group.—Teams of the 4th Auxiliary Surgical Group served in France and Germany with the Third U.S. Army, which became operational on 1 August 1944. Some of its teams, however, had gone ashore on Omaha and Utah Beaches on D+2. Two of its teams were flown to Bastogne on 26 December 1944, during the Battle of the Bulge, and were landed by glider not far from the German lines the same day that the 4th U.S. Armored Division broke through to relieve the city. Two teams, which were also landed by glider, were attached to the 17th Airborne Division for the cross-Rhine operation in March 1944.

The teams of the 4th Auxiliary Surgical Group cared for 27,516 casualties, of whom 1,040 are known to have had thoracic wounds. The 17,222 abdominal injuries for which it cared are not broken down into abdominal and thoracoabdominal categories.

5th Auxiliary Surgical Group.—The 5th Auxiliary Surgical Group was assigned to the Ninth U.S. Army after the middle of September 1944. Previously, some of its teams had served with the Fifth U.S. Army in Italy and, for a short period, with the Third U.S. Army in France.

The records are not complete, but it is estimated that the teams of this group cared for almost 16,000 casualties, of whom 1,063 had thoracic injuries and 300 thoracoabdominal injuries. The report points out, as had other reports, that the keeping of detailed personal case records was a luxury that had to be

sacrificed in periods of duress and heavy work, during which the great majority of these casualties were treated.

The teams of the 5th Auxiliary Surgical Group spent 80 percent of their time in field hospitals, in which operations were usually long and difficult and averaged 2½ hours each. The 7,829 casualties treated in these hospitals therefore required vastly more time and effort than the 8,069 casualties treated in evacuation hospitals. As in all other auxiliary surgical groups, the high case fatality rate during the first 24-hour period after operation implied the policy of operating on all casualties who had even a remote chance of survival. No accurate statistics are available concerning the number of patients admitted to forward hospitals who died before they could be operated on, or who were not operated on because their state was considered hopeless, but it is doubtful that they accounted for 2 percent of the casualties admitted to field hospitals.

Data on the thoracic surgical experience of this group appear in detail elsewhere (vol. II, appendix).

THORACIC SURGERY CENTERS

Establishment

On 6 December 1943, Colonel Cutler noted in his official diary that the theater chief surgeon did not wish specialized hospitals set up in the European theater. On further consideration, however, General Hawley reversed himself, and by D-day, a variety of hospitals for special treatment had been established. Thoracic surgery centers were included, although, as already noted, a thoracic surgery consultant had not then been appointed for the theater and none was ever appointed.

United Kingdom Base.—Circular Letter No. 81, issued on 10 June 1944 (*11*), designated centers for specialized treatment in thoracic surgery at:

1. The 15th Hospital Center. The chest center located at the 160th General Hospital was directed by Major Harken.

2. The 12th Hospital Center, Malvern Wells, Worcestershire. The chest center was directed by Colonel Touroff, at first at the 90th General Hospital and after 1 August 1944, at the 155th General Hospital.

3. The 6810th (U.S.) Hospital Center (Provisional), Whitchurch, Shropshire. This center, later the 804th Hospital Center, had active thoracic surgical services in several of its hospitals, and Colonel Miscall, chief of the Thoracic Section, Surgical Service, 137th General Hospital, served as coordinator for thoracic surgery. This installation, however, did not function as an active thoracic center in the sense that the thoracic centers at the 160th and 155th General Hospitals functioned.

Continent.—Shortly after D-day, the necessity for special centers on the Continent became evident. The first center for chest surgery was established in Paris, at the 48th General Hospital located at the 814th Hospital Center, on

6 November 1944, to serve the hospitals of the Seine Base Section. Its mission was to care for the thoracic casualties coming through the Paris area whose condition did not warrant their transfer to centers in the United Kingdom. It had an evacuation policy of 30 days, which meant that most patients had to be evacuated as soon as they reached the convalescent stage.

There were 348 admissions to the center at the 48th General Hospital during November and December 1944, upon whom the following chest surgery was performed, in addition to 9 bronchoscopies:

21 closures of wounds of the chest wall.
6 removals of foreign bodies from the chest wall.
3 debridements of the chest wall.
11 removals of foreign bodies from the lung.
15 drainage operations for empyema.
2 drainage operations for lung abscess.
1 drainage operation for mediastinal infection.
30 decortications.
1 ligation of the axillary artery.
1 repair of a congenital diaphragmatic hernia. An occasional operation of this kind was permitted in chest centers if the preexistent condition was giving rise to symptoms and if it was thought, as in this instance, that surgery could make the man fit for duty within a short time.

The plan for thoracic surgery and other specialized centers on the Continent was the outcome of discussions among the consultants at their meetings on 27 October and on 17 November 1944. The plan was to set up these centers at the largest concentrations of activities in the communications zone; that is, Paris, Liége, and Nancy. A circular letter that Colonel Cutler prepared after the November meeting (Circular Letter No. 32, Office of the Chief Surgeon, Headquarters, ETOUSA (*12*)) did not appear until 6 April 1945. It listed the following hospitals for specialized care:

15th General Hospital, 818th Hospital Center, Liége.
50th General Hospital, 819th Hospital Center, Commercy.
5th General Hospital, 820th Hospital Center, Toul.
23d General Hospital, Vittel.
43d General Hospital, St. Pons, Delta Base Section, SOLOC (Southern Line of Communications).

Ironically, by the time the circular letter designating these centers had appeared, the field armies had moved forward so rapidly that the general hospitals in the forward sections of the communications zone had been left far behind. As a result, casualties were reaching hospitals in the Paris area, and even hospitals in the United Kingdom Base, by air (fig. 12) more rapidly than they could be evacuated by land transportation to the intervening hospitals where specialized treatment facilities had been established. The war ended about a month after the circular letter designating these centers appeared.

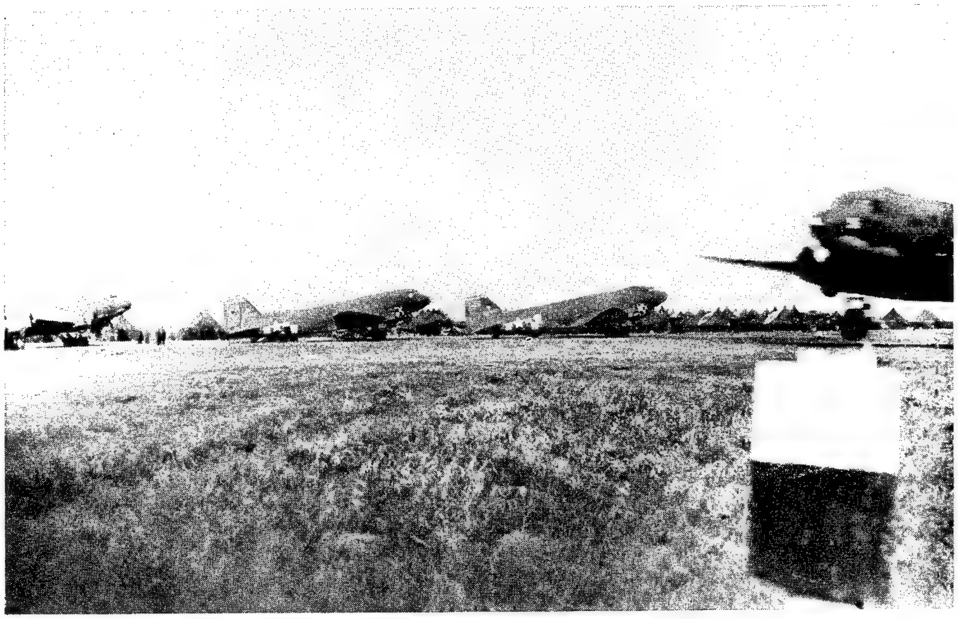


FIGURE 12.—Air evacuation from Continent to United Kingdom Base. C–47 transports ready to take off.

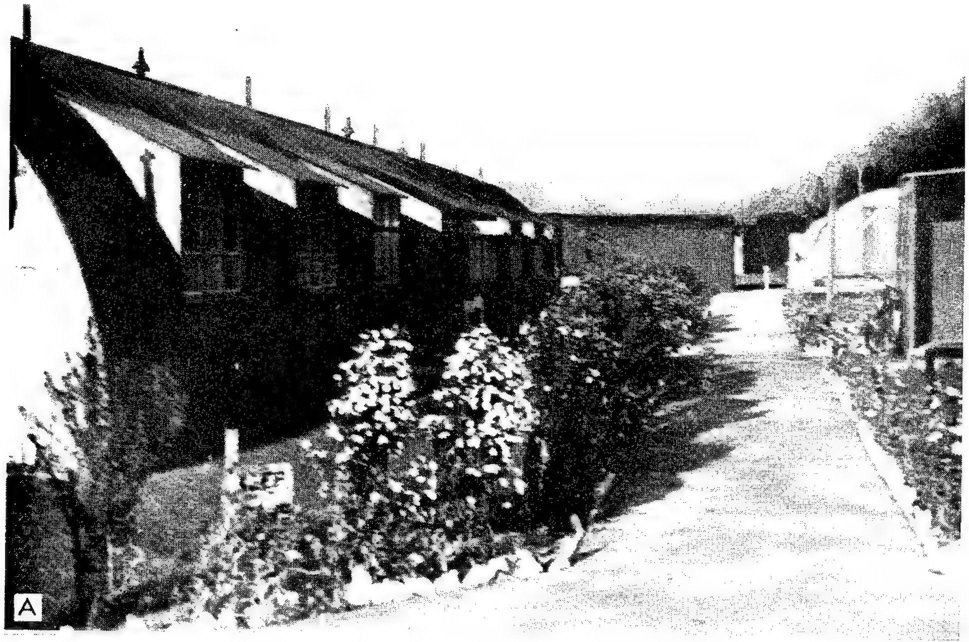
Facilities

Thoracic surgery and other specialized centers in the United Kingdom were established in U.S. Army hospital plants obtained by lend-lease (figs. 13 and 14). Some of the buildings were of temporary type construction, of brick and tile. Nissen huts and tents were also used, winterized for year-round occupancy. Some centers had as many as 200 buildings, 40 of which served as wards. When the patient load exceeded the current capacity, expansion into tents, equipped with stoves and lighting facilities, took care of the excess.

The grouping of several general hospitals, usually about 10, into hospital centers proved an extremely sound plan. Administrative problems were simplified, and more efficient use of professional and other personnel was possible. The two most active thoracic surgery centers that functioned in the United Kingdom Base operated under this plan.

Assignment of Casualties

Chest centers in the United Kingdom were originally not used to their full capacity because there was considerable confusion over how transfers to them were to be handled. Casualties with chest injuries are not mentioned in Administrative Memorandum No. 62, issued on 3 May 1944 (*13*). It was not understood, at first, whether transfers to the special centers were permissive or mandatory. Difficulties were ended as soon as it became clear that the individual



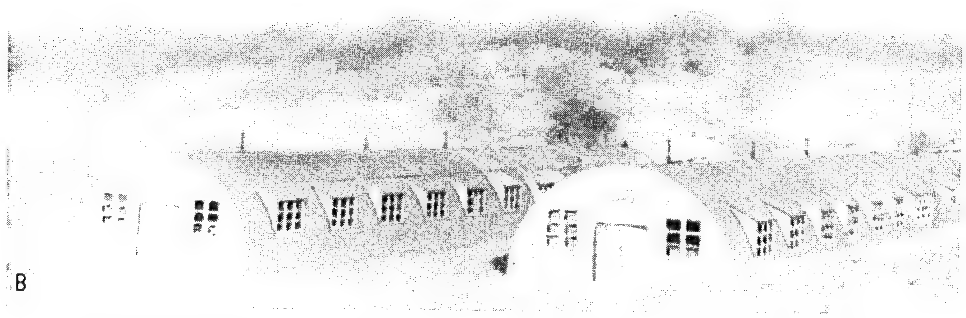


FIGURE 13.—160th General Hospital, site of thoracic surgery center. A. Headquarters building. B. Ward buildings.

FIGURE 14.—Thoracic surgery center at 155th General Hospital.

commanding officer or his chief of surgery would be responsible for their unsatisfactory course if patients who required specialized care were not transferred to a center for it. The thoracic centers, like the other centers, maintained good public relations and rendered good service. Good relations with the sources of their population were therefore soon established. Once this happened, the mechanics of transfer of patients furnished no further trouble. The entire relationship worked well not because of the rules but because of the fundamental sameness of objectives in all echelons of medical care.

The October 1944 meeting of the consultants in the Office of the Chief Surgeon, Headquarters, ETOUSA, was devoted in large part to improvement of evacuation practices, particularly a better classification of transportable and nontransportable patients and better care of patients in transit hospitals. At this meeting, General Hawley stressed that the care of patients in transit was just as important as their care in hospitals. At the November meeting of the consultants, it was agreed that the airlift should continue to be used, whenever it was practical, to evacuate casualties to the United Kingdom within 4 days after wounding. The situation improved, but in January 1945, when Colonel Cutler seized the opportunity offered by the Trench Foot Conference in Paris to discuss other matters, he found that personnel at thoracic surgery centers were still complaining that casualties were unduly long in reaching these installations. They were sometimes received as late as 30 days after wounding. These delays sometimes nullified the advantages of the special treatment facil-

ities and were responsible for patients being received in poor condition and unfit for prompt definitive treatment.

By no means were all casualties with chest injuries who were returned to base sections in the European theater evacuated to the chest centers in the United Kingdom Base. The policy was to admit these patients to general hospitals and then, if they did not show improvement under standard treatment within a short period of time, to transfer them to a chest center. It was estimated that not more than 5 percent of the casualties returned to the United Kingdom Base had chest injuries and that not more than 20 percent of these required treatment at thoracic surgery centers.

As a result of selection, the population of chest centers in the United Kingdom consisted of casualties who needed treatment more radical than delayed primary wound closure, evacuation of a hemothorax, or management of simple complications. In general, the distribution of injuries and complications that required treatment in chest centers, based on the experience of the 160th General Hospital chest center, was as follows:

Hemothorax, 70 percent; unclotted, 60 percent (infected, 3 percent); clotted, 10 percent (infected, 4 percent).

Retained foreign bodies, 15 percent of which about 8 percent required surgical removal.

Thoracoabdominal wounds, 8 percent.

Hematomas, 4 percent.

Injuries of the heart and pericardium, chiefly retained foreign bodies, 3 percent.

Obviously, in the light of these facts, the definitive treatment necessary in thoracic surgery centers consisted chiefly of:

1. The management of hemothorax and its complications, including such complications as clotting and organization.

2. The management of posttraumatic (hemothoracic) empyema, by drainage or pulmonary decortication.

3. The localization of intrathoracic and other retained foreign bodies, critical evaluation of the indications for their removal, and their removal as indicated.

4. The management of other complications, chiefly those associated with thoracoabdominal wounds.

Evacuation and holding policies.—A 120-day evacuation policy for the entire European theater was established in the middle of October 1944. In November, the same evacuation policy was established for the Seventh U.S. Army, which had just been brought under complete ETO control. Patients who required more than 30 days of hospitalization, but not more than 120 days, were to be evacuated to the United Kingdom Base or to SOLOC, the base section for the Seventh U.S. Army.

When the chest centers on the Continent were in the planning stage, it was Colonel Cutler's idea that strict specifications be set up for the duration of hospitalization in them. He believed that there should be a limit of 14 days.

Because of the delay in opening the planned centers, except for the center at the 48th General Hospital in Paris, and because of the success of air evacuation to the United Kingdom Base, this policy was never put into effect.

Holding limits in all the centers were loosely interpreted, and properly so, until V–E Day. As a result, many thoracic casualties were returned to duty in the theater who, by a stricter interpretation, would have been evacuated to the Zone of Interior and permanently lost to the theater manpower.

Advantages of Thoracic Surgery Centers

The thoracic surgery centers set up in the European theater were conducted, in general, by the policies that had proved so successful during the evolution and establishment of similar centers in the Mediterranean theater. As in that theater, the centers in the European theater had three chief advantages:

1. They permitted the concentration of casualties with chest injuries in hospitals especially equipped and staffed for their care.

2. They permitted the most efficient and economical use of the limited number of thoracic surgeons available in the theater.

3. As a result of the cumulative experience in these centers, it was possible to discard some policies that had proved ineffectual; alter others; and adopt new policies that had proved, by clinical trial, to be effective.

The establishment of thoracic surgery centers in the European theater had the same far-reaching effects as in the Mediterranean theater. Treatment was expedited. The definitive surgery necessary could be carried out with the most advantageous timing. Manpower losses were reduced. The crippling sequelae of chest wounds that had furnished a continuing problem after World War I were largely eliminated. The opportunity to study large numbers of patients permitted the adoption of new techniques with assurance of their advantages and disadvantages. Finally, younger officers who already had some experience in chest surgery could receive further training in these centers. This training was one of their most useful functions.

PRISONERS OF WAR

From the beginning of the fighting in the European theater, wounded and sick prisoners of war were cared for according to the provisions of the Geneva Convention.

Circular Letter No. 39, issued on 5 May 1945 (*14*), furnished instructions for hospitals utilizing the medical services of protected prisoner personnel in the care of prisoners of war. Commanding officers of the affected hospitals were to instruct these personnel in standard therapeutic procedures. The basis of the instruction was to be the "Manual of Therapy, European Theater of Operations" (*7*), and Circular Letters, all from the Office of the Chief Surgeon, No. 71, 15 May 1944 (*5*); No. 101, 30 July 1944 (*4*); No. 131, 8 November 1944

(*15*); and No. 23, 17 March 1945 (*8*). German medical officers were furnished with copies of the manual and these circular letters, which, together, contained all the basic policies for the management of the wounded.

If protected prisoner personnel were not capable of performing thoracic surgery, neurosurgery, or complicated plastic surgery, prisoners of war who needed such care were to be transferred to appropriate specialized centers. The experience in the European theater paralleled that in the Mediterranean theater, that captured German medical personnel were, for the most part, ill trained and inexperienced and that their surgical standards were remarkably low (p. 35).

According to the Geneva Convention, wounded prisoners of war had to be treated exactly as U.S. Army casualties were treated. After Major Harken made an investigation of complaints that some chest casualties being cared for by protected prisoner-of-war personnel were receiving unsatisfactory care, chest services were set up for them and were affiliated with the U.S. Army chest centers in the United Kingdom Base and on the Continent.

Section II. Basic Clinical Considerations

EVOLUTION OF CLINICAL POLICIES

General Policies

In the European theater, in spite of the efforts to disseminate the knowledge gained from the experience in the Mediterranean theater, the management of chest injuries progressed through a cycle, much as in that theater. In the beginning, before surgeons had much actual experience with combat wounds, the general tendency was to be radical, and there were few casualties with chest injuries who did not undergo thoracotomy. When casualty loads became heavier, however, and there was a large backlog of patients with abdominal and thoracoabdominal wounds with high priority for surgery, thoracotomies were necessarily fewer. It was thus learned that patients with thoracic injuries could be handled with better results by delayed surgery and by less radical surgery.

Eventually, the indications for thoracotomy were stabilized about as follows:

1. Hemothorax caused by active bleeding which rapidly refilled the chest cavity after aspiration. Patients in this category were frequently in severe shock on admission and did not respond well to resuscitation. The source of bleeding was usually an intercostal or internal mammary artery, the lung itself, or, less often, the heart or some other mediastinal structure.

2. Massive clotted hemothorax that did not lend itself to aspiration. Patients in this group often presented dyspnea, cyanosis, and mediastinal shift.

Evacuation of the clotted blood and control of bleeding were readily effected through an open thoracotomy and made this operation the procedure of choice.

3. The presence of foreign bodies 2 cm. or larger in the pulmonary parenchyma or pleural cavity. The principal indication for their removal was the risk of infected hemothorax and lung abscess, but other indications were possible further damage to the lung or laceration of some blood vessel.

4. The presence of shattered rib fragments in the lung or pleural cavity or of large fragments that had not perforated the pleura. These required removal either by thoracotomy or by extrapleural rib resection. Many surgeons in the European theater came to agree with surgeons in the Mediterranean theater that bone fragments in the lung were potentially more serious than metallic foreign bodies. They were apt to be long and sharp with irregular edges, so that they could penetrate the tissues and forge ahead in them. After a time, these detached bone fragments became necrotic, and an abscess or an infected hemothorax was a likely consequence. Laceration of a blood vessel was always far more likely from contact with bone fragments than with metallic foreign bodies.

5. Sucking wounds. This type of wound always demanded definitive treatment. If simple debridement and wound closure were not adequate, and if it was known that there was intrathoracic damage of consequence, thoracotomy was indicated.

6. Tension pneumothorax due to an air leak, as in bronchopleural fistulas.

After these indications had become established, the treatment of thoracic casualties in the European theater became more conservative. There were still many departures from official policy, however, usually attributable to (1) the desire of surgeons to follow their personal preferences and (2) the difficulty of teaching them that, in wartime, policies must be standardized and that the procedure proved by group experience to be safest must be employed rather than the policy which the individual surgeon happened to consider best.

The material in the "Manual of Therapy, European Theater of Operations," issued on 5 May 1944, provided the basic principles for all surgical procedures in the theater, including wounds of the chest. Circular letters (p. 123) were issued later, to elaborate or modify various procedures in the light of experience, as well as to reemphasize certain policies that were not being followed.

The chief surgical error was the omission of adequate debridement. Next came the closure of wounds under tension, by pulling the edges together, instead of employing techniques of closure such as undermining incisions or split-thickness skin grafts. Dumping of sulfonamide powder or crystals into wounds simply made subsequent closure more difficult.

Originally, many casualties were evacuated to base hospitals with large collections of fluid in their chests. Special attention was directed to this error, but often it was not considered feasible to carry out routine roentgenologic examination or aspiration of the chest before evacuation.

Special Policies

Wound closure.—The first procedure in most patients received in a base hospital was prompt closure of wounds that had been left open at initial wound surgery. The early experience in the Mediterranean theater had shown the disastrous consequences of primary suture, and the later experience had shown the excellent results of delayed primary wound closure, which was therefore the general policy in the European theater.

Principles and practices were the same as in wounds of other parts of the body. The routine culture of wounds was found to be unnecessary and to be wasteful of both time and material. As in the Mediterranean theater, only a brief experience was necessary to show that the clinical appearance of the wound was sufficient criterion for its closure or nonclosure. Cultures were made only when there was clinical evidence of infection and the information would be useful for subsequent clinical management.

In judging the suitability of a wound for closure, it was the practice at a number of hospitals in the theater to elevate only the outer dressing, leaving the fine-mesh gauze directly over the wound still in place. The gauze directly over the wound was not removed until the patient was in the operating room. If no sign of infection was evident through the gauze, the patient was scheduled for delayed primary wound closure. This was a practical method of determining the feasibility of closure. It reduced the risk of infection, and it saved time in the operating room.

If the wound was not clean, as indicated by induration or exudation, continuous compresses were used for from 24 to 48 hours. If devitalized tissue was present, redebridement was performed before closure, which was delayed for another 3 or 4 days.

In large soft-tissue defects, in which undermining procedures did not permit closure without tension, the prompt use of split-thickness skin grafts saved weeks of slow healing. This plan was also better than too radical undermining, in an attempt to secure satisfactory flaps for closure.

Associated wounds.—Even if the casualty had associated head injuries or compound fractures of greater seriousness than the chest wound, it was the best policy to care for the chest wound first, in order to restore cardiorespiratory balance. Thoracoabdominal wounds always took precedence over other wounds. If the patient's condition at the conclusion of the thoracic or thoracoabdominal procedure was poor, operation for associated injuries was deferred for from 24 to 72 hours. The risk of development of infection in these wounds was less than the risk of subjecting a thoracic casualty who was in shock or had just been brought out of shock to additional trauma and blood loss without an interval for further resuscitation and stabilization.

Fractures of the humerus and shoulder girdle, which were often associated with wounds of the chest, introduced problems if postoperative aspiration of the chest was necessary. In some cases, a plaster Velpeau dressing was

applied and a window cut in the chest portion for this purpose or, if drainage had been instituted, to permit the exit of the catheter. In many cases, temporary dressings of elastic or adhesive bandages were applied in Velpeau fashion for the immediate postoperative period. They were replaced later by a plaster Velpeau or by a thoracobrachial cast for transportation. Hanging casts were very effective in base hospitals. Some patients with fractures of the supracondylar portion of the shaft of the humerus were put up temporarily in full arm casts, and suitable transportation casts were substituted before evacuation.

Adjunct therapy.—The policies of replacement therapy set up in the Mediterranean theater on the basis of its early experience were generally followed in the European theater. The lessons of the inadequacy of plasma had been well learned in the Mediterranean theater, and the errors originally made there were not repeated in Western Europe. Shortages of supply imposed some limitations upon the use of blood in the first weeks after D-day, but when once blood began to be flown to Europe from the Zone of Interior, all restrictions were removed, and every casualty received as much as he needed.

At the beginning of the campaign in Europe, it was still the practice to sprinkle all wounds in body cavities with sulfanilamide crystals or with a mixture of dry penicillin and sulfanilamide. Later, local therapy was omitted because systemic therapy was found to be adequate. Instillations of penicillin were used in the chest cavity (p. 296). Otherwise, only systemic therapy was used, by the policies established in the Mediterranean theater. Since penicillin was administered in all cases in which it was believed to be indicated, no control series was run, and it is therefore impossible to determine the effects of antibiotic therapy on the end results. There was no doubt, however, that the basic reason for the good results secured was good surgery, with the sulfonamides and penicillin playing a very significant part, if comparison with comparable wounds in World War I had validity.

MANUAL OF THERAPY, EUROPEAN THEATER

General guidance for the management of wounds of the chest was contained in the Manual of Therapy, published in the European theater in May 1944 and distributed to all medical officers.

Wounds were divided into three types:

1. Wounds limited to the chest wall, which were managed as any other soft-tissue wound.

2. Wounds that perforated or penetrated the pleural cavity or lung without resulting cardiorespiratory embarrassment. These wounds required no specific treatment in forward areas beyond proper treatment of the external wound and priority evacuation, to permit prompt treatment of any complications that might develop.

3. Wounds associated with cardiorespiratory embarrassment. The recognition of these wounds and the associated pathologic processes was essential because management was lifesaving and often had to be instituted in forward areas.

The manual listed the important points of diagnosis in open pneumothorax, tension (pressure) pneumothorax, crushing injuries (stove-in chest), hemorrhage, subcutaneous emphysema, and blast injuries. In penetrating wounds of the chest in which the missile was not seen in the roentgenograms, additional roentgenograms should be made of the abdomen.

The following instructions were given for the emergency and definitive management of chest injuries:

Emergency Measures

1. In open pneumothorax, the primary consideration is closure of the opening in the chest wall, which is best done by the application of a large, sterile, petrolatum-impregnated gauze pad, supported by a bulky gauze dressing held firmly with adhesive tape. To avoid the danger of tension pneumothorax, the dressing should be almost, but not absolutely, airtight. If the wound is large and gaping, it may be necessary to suture the gauze pad in place, to prevent its loss into the pleural cavity. In an emergency, anything can be used to occlude the opening, even a sterile pad held over the wound by the hand, which will save life until more adequate measures can be instituted. The patient should lie on the affected side.

2. In pressure pneumothorax, a needle is introduced through the second interspace anteriorly on the involved side to allow the trapped air to escape. As a precaution against recurrence, and always if air continues to escape, the needle should be reinserted through a cork strapped in place and covered with a condom or finger cot, so that a valve is produced.[2] In place of the needle, a small catheter may be introduced through an incision in the thoracic wall and attached to a closed drainage system.

3. In crush injuries, pain is relieved by intercostal nerve block. In extensive bilateral injuries, an attempt may be made to stabilize the chest wall by circular adhesive strapping. Paradoxical movements of the chest wall are controlled by strapping the injured side only.

4. Marked cyanosis indicates possible bronchial obstruction. Nerve block should be performed, and the patient encouraged to cough vigorously. These measures, with the head-down position,[3] may clear the bronchial tract. The patient must not be left alone in this position, for fear of respiratory embarrassment.

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[2] So far as is known, this method was not used in the European theater. It is a traditional technique, but it is not always either practical or effective.

[3] Experience showed that the head-down position was a very bad position for a thoracic casualty and that catheter aspiration or bronchoscopy was the correct way to clear the tracheobronchial tubes.

5. In external bleeding, the wound should be inspected, to determine obvious bleeding points. If the site of the wound suggests possible injury to the internal mammary or intercostal vessels, an attempt is made to secure the ends of the severed vessels with hemostats and then ligate them. If the attempt fails, the wound is enlarged sufficiently to permit temporary digital control by compression of the bleeding point against the chest wall, after which deep transfixing sutures are used. If no bleeding point is found, firm packing is employed. The patient is treated for shock.

6. Subcutaneous emphysema usually needs no treatment. If it has developed after airtight closure of an open sucking wound, the associated tension pneumothorax must be treated.

7. In blast injuries, absolute rest is more important than immediate evacuation to the rear. Oxygen is of great value, but neither plasma nor blood affects the associated collapse.

Thoracoabdominal wounds are not discussed as such under emergency measures beyond the statement that any projectile that enters the chest must be regarded as a possible cause of abdominal injury.

Definitive Treatment

General measures.—The following general measures were employed:

1. The patient should be kept on the injured side or sitting up and should be disturbed as little as possible during examination.

2. Large doses of morphine should not be given, as they abolish the cough reflex. Intractable pain is better controlled by intercostal nerve block.

3. Open pneumothorax and rapidly progressive pressure pneumothorax are grave emergencies, but once they have been controlled, there is no need for further emergency procedures, and there can be deliberate consideration of what comes next.

4. Associated thoracic injuries should be suspected in all wounds of the upper arm, cervical region, and abdomen. Roentgenologic examination is essential for diagnosis.

5. Hemorrhage requires adequate blood replacement, as in other injuries.

6. Acute gastric dilatation is a common accompaniment of chest injuries and often accounts for disproportionately great dyspnea. The complication is potentially lethal but responds readily to decompression by the Levin tube. It should be specifically sought for in all roentgenologic examinations of the chest. It is easily recognized.

7. Untreated effusions of serum and blood are the commonest avoidable causes of complications. The pleural space must be kept empty.

8. Bronchoscopy is of inestimable value whenever the bronchi and trachea are obstructed by mucus or other excessive secretions. It is often a lifesaving measure both before and after operation.

9. Local analgesia is suitable for injuries of the chest wall. For intrathoracic surgery, positive pressure anesthesia is essential, preferably through an endotracheal tube. Intravenous Pentothal sodium (thiopental sodium) should be avoided in the presence of respiratory embarrassment.

10. Drainage tubes should be securely anchored to the chest wall. Their loss in the pleural cavity during evacuation is an avoidable cause of late complications.

11. Postoperative measures include precautions against, and prompt diagnosis of, acute gastric dilatation; oxygen therapy; repeated aspirations of the pleural space if effusion occurs; bronchial aspiration in the management of atelectasis; and early, active breathing exercises, to shorten convalescence and avoid deformities of the chest wall.

Special injuries and complications.—Certain injuries and complications furnished special problems, as follows:

1. *Open pneumothorax.*—In open pneumothorax, the dressings are not disturbed until the patient is prepared for operation. Debridement is performed, with such intrathoracic surgery as is indicated, followed by airtight closure of the chest wall and reinflation of the collapsed lung. A large defect may be repaired by the combined use of the diaphragm and a large muscle of the chest wall, such as the latissimus dorsi or pectoralis major. Occasionally, it is necessary to suture the lung to the margin of the wound. Intercostal closed catheter drainage is instituted through a separate incision, in a dependent position, if it is required because of contamination of the pleural cavity and the risk of sepsis. If drainage is omitted, the patient must be watched carefully for subcutaneous emphysema or pressure pneumothorax.

2. *Tension pneumothorax.*—Tension is relieved by aspiration of air from the involved side through the second interspace anteriorly. A flutter valve is inserted, or closed drainage is instituted as a precaution against recurrence.

3. *Hemorrhage.*—Bleeding from the lung usually ceases spontaneously, but a pulmonary wound close to the root of a lobe may be the source of major bleeding that must be controlled by suture, or by partial resection and suture, of damaged pulmonary tissues. Bleeding from the intercostal and internal mammary vessels, the most frequent sources, can be suspected from the location of the wound. It is readily controlled under suitable operating conditions. Wounds involving the great vessels at the hilus are usually rapidly fatal, but early intervention and heroic surgery may occasionally be lifesaving. It should be remembered that a casualty can bleed to death into the pleural cavity without any mechanical embarrassment to the cardiorespiratory system.

4. *Hemothorax.*—A hemothorax should be evacuated within 48 hours, in order to reduce the chances of infection, prevent loss of pulmonary function by the development of fused chest, prevent deformity, and shorten convalescence. If the blood has not clotted, simple aspiration is sufficient, without introduction of air. If the blood has clotted but is uninfected, the clots are broken up and removed through a cannula. If this is impossible, it may be necessary to

make an intercostal incision to evacuate them. The chest is then closed and air aspirated from it. If infection has occurred, as shown by characteristic roentgenograms, the treatment is that employed for empyema. An attempt is made to remove the clot without risking contamination of adjacent walled-off uninfected pleural space.

5. *Foreign bodies.*—A conservative attitude is best. Foreign bodies should be assumed to be in the subcutaneous tissues or the parietes until they are proved unequivocally to be in the lung. Precise localization by roentgenogram is necessary before a plan of management is determined. Smooth foreign bodies, less than 2.5 cm. in diameter, seldom require urgent removal. Large, irregular objects should be removed as soon as possible because of the high incidence of serious infection arising from them. They are usually present in wounds that require debridement down to the pleural cavity. A shattered rib on the side of entry, regardless of the status of the external wound or the characteristics of an associated retained missile, requires thorough exploration of the wound of entrance and the pleural space. Explosive costal injuries are often associated with extensive damage to the lung, and rib fragments prove to be troublesome foreign bodies.

6. *Crushing injuries.*—The treatment already described (p. 143) is continued. In most bilateral injuries, and in some unilateral injuries, the thoracic wall should be stabilized and elevated by perichondrial wire sutures or towel clips; they are attached to the mobile sections of the fractured ribs and then used to provide traction. The sutures or clips are left in place until the chest is stable, a minimum of 3 weeks.

7. *Blast injuries.*—The most important phases of treatment, as already described, are oxygen and absolute rest. Chemotherapy is used to prevent infection. If surgery is imperative for other injuries, inhalation anesthesia is avoided.

8. *Thoracoabdominal injuries.*—A thoracic approach is employed only when injuries of the thorax require urgent surgery to save life. If it is used, the diaphragmatic wound may be radically enlarged and the abdomen explored through it. Wounds of the stomach and spleen may be readily handled by this route. If exploration through the diaphragm is unsatisfactory, a secondary abdominal incision should be used after the chest surgery is completed. The diaphragm is closed by overlapping the lacerated margins with nonabsorbable sutures. Low phrenic crushing is done to keep it at rest. Repair of lung damage with closed intercostal drainage may be indicated. If the liver is lacerated, the subdiaphragmatic space is packed and drained posteriorly below the diaphragm. The patient should be observed for empyema and intra-abdominal complications, especially subphrenic abscess.[4]

[4] As their experience accumulated, many surgeons came to prefer the transthoracic approach to thoracoabdominal wounds, employing it on the indications and contraindications established in the Mediterranean theater (vol. II, ch. III). Packing in hepatic wounds was also discontinued in favor of simple drainage, though this never became official theater policy.

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REPORTS OF CHEST CENTERS IN THE UNITED KINGDOM BASE

A composite summary of the reports of the chest centers at the 160th General Hospital and the 155th General Hospital is appended, to show the workload and activities of these installations.

160th General Hospital

The 160th General Hospital reached the United Kingdom on 27 April 1944.[5] On 10 June 1944, it was designated a thoracic surgery center (the first to be set up in the European theater) for the 15th Hospital Center. Major Harken, who had previously been working in General Hawley's office in Grosvenor Square, was sent to the center as director on General Hawley's personal orders. The assignment was entirely to his liking, for, as he had told Colonel Cutler and General Hawley many times, he personally believed that thoracic surgery should be recognized as an independent surgical specialty. In all of his contacts with U.S. chest surgeons, Mr. Tudor Edwards expressed the same opinion and pointed to the results being achieved in British chest centers by implementation of this concept.

Personnel.—The personnel of the center varied considerably during the 13 months of its operation. Major Harken, the chief anesthesiologist, Capt. (later Maj.) Charles L. Burstein, MC, the senior ward nurse, and two of the surgical nurses served throughout this period. Captain Burstein was a highly competent anesthesiologist and a productive investigator. 1st Lt. (later Capt.) Margaret Evans, ANC, the senior ward nurse, was a woman of great capacity, both as a bedside nurse and as a teacher. She exercised remarkable disciplinary control over her patients, who did what she expected of them because of their affection and respect for her.

Later, two excellent additional surgeons were assigned to Major Harken at the thoracic surgery center, Capt. Joseph P. Lynch, MC, and Capt. Ashbel C. Williams, MC. Their assistance made it possible to teach and train a number of surgeons who were attached to the center on temporary duty at various times.

This nucleus of officers and nurses was augmented, at different times, by other medical officers and other personnel, and by extremely competent thoracic surgical teams from the 1st Auxiliary Surgical Group.

Enlisted men and convalescent patients were used for rehabilitation instruction and demonstration. It was possible, by standardizing all procedures, including preoperative and postoperative care, to perform a maximum amount of work with minimum help as soon as sufficient experience had been accumulated to determine the best policies and practices.

Training.—When the 160th General Hospital was activated as a thoracic surgery center, the professional activities of the entire hospital were minimal.

[5] These data are derived from the semiannual reports of the 160th General Hospital chest center for July-December 1944 and January-June 1945 and from a supplementary report made by Major Harken to Colonel Cutler on 9 November 1944.

In the few weeks before D-day, it was therefore possible to select and train ward and operating personnel, as well as nurses, with special interest in chest surgery and in anesthesia (p. 122).

Reports and records.—The surgical staff found time, amid their professional activities, to prepare several articles for publication. They made frequent presentations at meetings and conferences. They prepared specimens for the Army Medical Museum and also took motion pictures not only of unusual cases but to demonstrate the techniques most frequently used in such an installation.

In his first report to Colonel Cutler, in November 1944, Major Harken reminded him that he (Colonel Cutler) had pointed out that an important aspect of the mission of a chest center was to share its experiences with others. This was difficult because of the lack of secretarial help. The staff had to maintain its own records, and such information as could be salvaged, beyond the required official records, was produced by the efforts of a badly overworked staff, who frequently felt that they were fighting a losing battle.

Population.—The first patient received in the thoracic surgery center, a few days after it had been activated, was an Army Air Force sergeant who had been injured over Germany. He had been treated in a succession of hospitals for an infected hemothorax that had long since become a chronic empyema. The rib-resection drainage performed successfully at the 160th General Hospital was the first operation in a chest center in the European theater. This same technique was used in all extensive empyemas treated by rib-resection drainage in this center (fig. 15).

Casualties from the Continent began to be received on D+4, and by the time the center was deactivated, it had received 1,859 casualties by direct admission. Additional patients received by transfer from other sections of the hospital center brought the total number treated in the chest center to more than 2,000. The expansion of the center was so rapid that 500 patients were sometimes under treatment at the same time.

These figures do not include a certain number of chest casualties who were treated in other hospitals in the United Kingdom Base because they were too ill to be moved. On these occasions, Major Harken several times took a team, including one or two assistant surgeons, an anesthesiologist, and one or two surgical nurses, to the hospitals in question. They traveled at night, by ambulance, and operated during the day.

Because of the limited bed capacity and personnel at the center, every effort was made to limit admissions to the 160th General Hospital chest center to real surgical problems. Other patients were treated in the referring hospitals, by standard policies, and were moved to the thoracic surgery center only if their progress was not satisfactory. If this plan had not been followed, the census would have run well past 3,000.

A great many of the casualties received at the 160th General Hospital arrived by air. This was a satisfactory means of transport if pneumothorax was not present. A nearby airport made transport to this center easier and

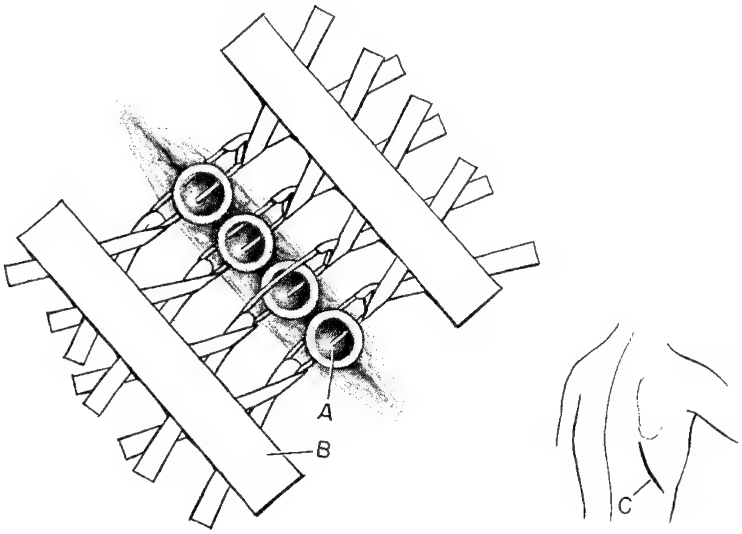

FIGURE 15.—Technique of drainage of empyema employed at 160th General Hospital thoracic surgery center in United Kingdom Base. A. Rubber drainage tube. B. Adhesive used to stabilize drainage tube. C. Site of frequently used posterolateral drainage of posterior empyema pocket. Note.—Surgeons in the Mediterranean theater (q.v.) preferred another technique, which they considered simpler and more adequate.—F.B.B.

faster than to some geographically nearer installations. Casualties from the Rhine were often on the operating table at this hospital the same day they were wounded.

Case fatality rates.—During the operation of this center, 1,065 major operations were performed on 951 patients. When two procedures were necessary, they were usually performed at the same sitting. Over the same period, 249 minor operations were performed on 248 patients.

The case fatality rates were a source of great satisfaction. There were only 12 deaths in the 951 surgical patients (1.4 percent), 2 in 493 foreign body removals, 1 in 203 decortications, and 9 in 170 rib resections for empyema.

While young, vigorous U.S. soldiers proved generally excellent surgical risks, many patients were received in poor condition because of the nature of their wounds; the nature and degree of associated physiologic dysfunction; and, in a certain number of cases, previous inadequate or unwise treatment. The number of patients in the latter category decreased as time passed.

Six other deaths occurred among patients with thoracic injuries who were not admitted to the center but whose thoracic component was being supervised on the wards on which they were being treated for associated conditions. Two patients had empyema and lung abscesses, which had not responded to previous drainage. One of these died of a suppurative thrombophlebitis and the other

of a high cord lesion, with a spinal fluid fistula into the pleura. Another patient had a fatal transfusion reaction, and still another died of exsanguination before surgical intervention was possible. At autopsy, the source was found to be an area of erosion from the aorta into the esophagus. The foreign body was in the stomach.

Numerous factors might be adduced to explain the good results obtained at this center. Among them were:

1. Very careful preoperative preparation.
2. Excellent anesthesia.
3. The increasing experience of the chest surgeons and their assistants, gained from the observation of such a large concentration of chest casualties.
4. An excellent system of rehabilitation, based on remedial breathing exercises. The personnel of this center preferred to handle personally as much of the rehabilitation of their patients as was practical. They regarded rehabilitation as part of therapy and believed that when it was segmentalized, it lost a major degree of its effectiveness. The special exercises employed are described in detail elsewhere in this volume (p. 314).

Anesthesia.—Anesthesiologists at the center individualized their patients and used the types of anesthesia for them most suited for their special problems. Their objects were to protect the patient from untoward reflex changes, assure ample oxygenation, provide adequate ventilation for elimination of carbon dioxide, reduce annoying motion of the intrathoracic viscera to a minimum, and produce as little disturbance as possible of normal physiologic function.

The following technique was devised, or, more correctly, evolved, to achieve these objectives:

1. Rapid induction with a relatively large dose of Pentothal sodium except in patients who had suffered recent hemorrhage or were poor risks for other reasons. Then the amount of the drug was greatly reduced.
2. Intubation with a large-bore Magill endotracheal tube with an inflatable cuff.
3. Maintenance of anesthesia with nitrous oxide, oxygen, and ether, with the use of compensated respiration (continuous manual reinforcement of the automatic respiratory effort). A constant flow of from 5 to 7 liters of oxygen per minute was maintained.
4. The use of whatever procedure was necessary to prevent untoward cardiocirculatory reflexes and peripheral circulatory depression.

This technique proved both safe for the patient and satisfactory for the surgeon. Many anesthesiologists who employed it had had relatively little general training in anesthesia, but all had had special training in this method and all worked under the continuous supervision of experienced and highly trained anesthesiologists, who themselves usually cared for bad-risk patients or those likely to present special difficulties.

From the Standpoint of anesthesia, thoracic operations fell into two groups:

1. Thoracotomy for intrathoracic exploration required endotracheal intubation, so that pulmonary ventilation could be controlled. Induction was performed with intravenous Pentothal sodium alone or combined with nitrous oxide, so that the electrical Bovie unit could be used at the beginning of the operation. The larynx was cocainized with 4 percent cocaine before intubation if the glottis and vocal cords seemed hyperactive. Ether anesthesia was begun when the chest was opened and there was no further need for the Bovie unit. Cardiovascular reflexes due to stimulation of branches of the vagus in the hilus of the lung or in the mediastinal structures were watched for, and controlled by local injection of 1 percent procaine hydrochloride. The surface of the heart was kept moistened with a solution of procaine hydrochloride when cardiac manipulations were necessary. The involved intercostal nerves were injected with from 3 to 5 cc. of procaine hydrochloride (1½ percent in oil) to prevent the shock that might follow spreading of the ribs during thoracotomy, as well as to decrease postoperative pain.

2. Rib resections for drainage of empyema were usually performed under light anesthesia secured by intravenous Pentothal sodium supplemented by nitrous oxide with oxygen in liberal amounts. This technique was considered superior to local analgesia, since it reduced the time required for operation and provided good oxygenation for a patient lying on his intact side during the procedure. Several patients who were extremely toxic from putrid empyema required unusually high concentrations of oxygen, and cyclopropane was used for them.

Retained foreign bodies.—The fascinating experience of the 160th General Hospital thoracic surgery center with retained foreign bodies in the heart, pericardium, and great vessels is described in detail elsewhere (vol. II, ch. VIII). The experience with the removal of retained foreign bodies in the lung was similarly favorable. Several studies showed that it was possible to operate on a patient and transfer him to a reconditioning center for return to duty in the theater more rapidly than he could be handled by a disposition board and returned to the Zone of Interior.

Hemothorax.—As the war progressed, clotting of uninfected hemothorax was observed less frequently, and fewer patients in this group required surgery, probably because of the increasing efficiency of treatment in forward hospitals. The majority of the patients received with hemothoraces could be treated by a combination of complete aspiration and breathing exercises. Decortication was employed when the hemothorax had clotted or had become infected.

For reasons that are not clear, the number of patients admitted with grossly infected hemothoraces was larger in 1945 than in 1944. These patients, like those with clotted hemothoraces, were treated by decortication.

Empyema.—A small number of patients with basilar empyema, whose cavities did not exceed 500 cc. in volume, were treated by open drainage. This policy was based on four major premises:

1. Early, adequate drainage. The site, always dependent, was selected after routine roentgenologic examination, mapping of the lesion after the instillation of Lipiodol, and aspiration.
2. Maintenance of the wall of the empyema cavity in an acute inflammatory state, so that obliterative pleuritis would proceed rapidly. The frequent application of irritating packs tended to maintain the desired acute pleuritis.
3. Maintenance of the nutritional state by appropriate diet, accessory vitamin therapy, and replacement therapy as indicated.
4. General and specific remedial exercises (p. 314).

A small number of patients who were in poor or critical condition when they were received in the center were treated by open drainage, in preparation for later decortication. As a rule, they were ready for the more radical operation in from 7 to 14 days. Open drainage was also used for the small localized residual empyemas sometimes observed after decortication.

Rib-resection drainage (fig. 15) was performed in 170 cases in which the empyema was too extensive to be managed by open drainage.

Decortication.—Decortication was used with increasing frequency, and with improving results, as the war progressed. The approach, however, was always conservative. The indications were as follows:

1. Clotted hemopneumothorax associated with acute cardiorespiratory embarrassment, overwhelming sepsis, or both. In such cases, the extensive loculation and clotting made both aspiration and rib-resection drainage unsatisfactory.
2. Any hemothorax in which the accumulation of clotted, infected blood was estimated to be more than 700 cc. Smaller accumulations could usually be handled satisfactorily by more conservative measures.
3. Obscuration of at least half of the involved lung field, with no evidence of clearing under attempts at aspiration and the institution of active breathing exercises, as determined by weekly fluoroscopic and roentgenologic examinations. When the obscuration was greater than half the lung field and remained stationary for more than 2 weeks, decortication was usually resorted to without further delay. With proper roentgenologic techniques, it was possible to outline the extent of the hemothorax and the encompassing membrane fairly clearly.

The technique used was, in general, that employed in the Mediterranean theater, where the operation was first introduced for organizing hemothorax and hemothoracic empyema (p. 27). If a foreign body was retained in the lung, it was removed at the same operation.

A primary cure was obtained in possibly 75 percent or more of all cases. If infection persisted, the empyema was usually small and localized, and open drainage rapidly effected a cure. In some cases, the cause of failure was found

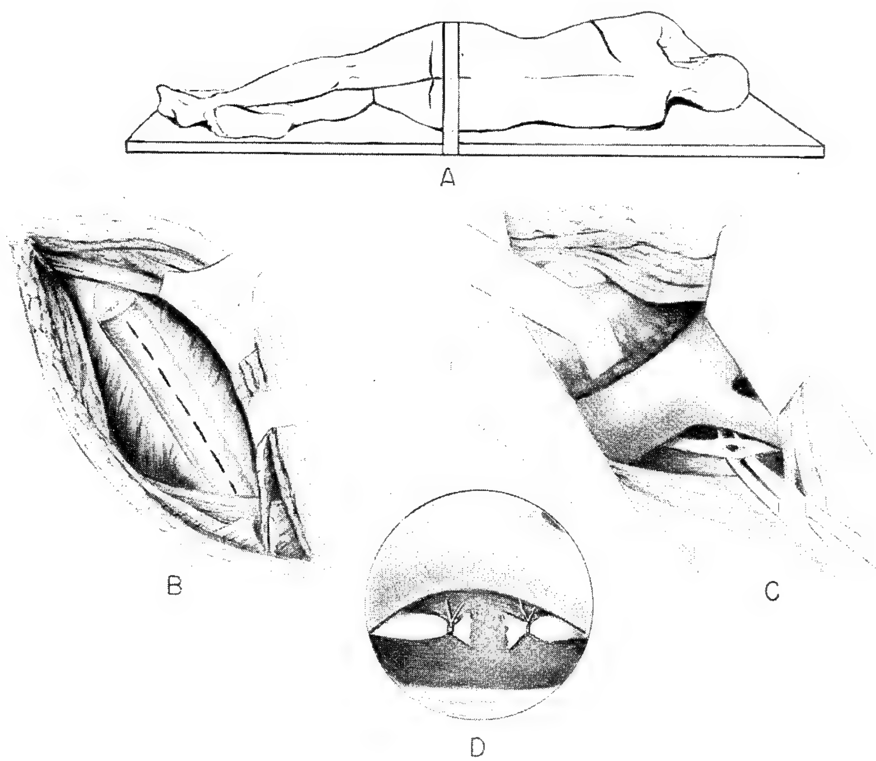

FIGURE 16.—Technique of ligation of lacerated thoracic duct. A. Posterolateral incision. B. Bed of fifth rib, which has been resected. C. Isolation of duct above aorta and behind left subclavian artery. D. Double ligation of duct. Decortication was also performed. Recovery was uneventful (160th General Hospital thoracic surgery center).

to be a persistent bronchopleural fistula, which prevented complete reexpansion of the lung. These patients were treated without delay by continuous high negative pressure. They were placed on suction drainage applied from a suction line set up in one of the wards, the lung thus being held in expansion until the fistula closed.

Chylothorax.—Two patients were observed at the center with chylothorax following perforating chest wounds. One, who had a moderately large cystic area in the upper left lung field, was treated by repeated aspiration of chyle from it. Convalescence was prolonged, but the response was favorable, and no further treatment was required.

The second patient had a massive effusion through which large quantities of chyle were repeatedly aspirated. When no signs of improvement were evident, the thoracic duct was ligated (fig. 16), and decortication was performed. The result was excellent.

Diaphragmatic hernia.—It was the policy at the center to repair all hernias of the diaphragm that were diagnosed, no matter how small the per-

foration might be, on the ground that otherwise the opening would inevitably increase in size and permit herniation of abdominal organs. Operations for herniations that had already occurred, particularly herniations of the stomach, were often technically difficult.

Lobectomy.—The 951 operations performed at the 160th General Hospital chest center included 15 lobectomies. This operation was used only when the lobe, or part of the lobe, was damaged beyond repair. Sometimes the tissue was found to have been actually blasted away. Whenever possible, the Blades-Kent technique of individual ligation, which had been described shortly before the war, was used in these cases.

Thoracoabdominal wounds.—Fifty-six patients with suppurative complications of thoracoabdominal wounds were treated at the chest center at the 160th General Hospital. The data are as follows:

As was usual, the initial location of the wound greatly influenced both the number and the seriousness of the complications. There were 46 complications on the right side, against only 10 on the left. They were classified as follows:

1. Of the 15 instances of subphrenic infection without pleural involvement, 14 were on the right side, including 7 subphrenic abscesses, 6 hepatic abscesses, and 1 combined subphrenic-hepatic abscess. The single infection on the left side in this group was a subphrenic abscess. All 15 infections were successfully treated by conventional subphrenic drainage.

2. Of the 42 instances of subphrenic infection with pleural involvement, 32 were on the right side. They included 30 infected hemothoraces, 2 with subphrenic and 28 with hepatic abscesses, and 2 uninfected hemothoraces, 1 with a subphrenic and 1 with a hepatic abscess. The 10 infections on the left side included 2 uninfected hemothoraces, both with subphrenic abscesses, and 7 infected hemothoraces. In this group there were two herniations of the stomach and two gastropleural fistulas.

In the infections with pleural involvement, management depended upon whether or not the diaphragmatic perforation was sealed off. If it was, the pleural and subphrenic lesions were treated independently, by standard techniques. If the perforation was still open, the treatment depended upon the size of the thoracic component:

1. If an empyema with an associated liver abscess was shown by roentgenograms to be small, it was opened widely by rib resection, and the hepatic abscess was deroofed by removal of the overlying diaphragm and was drained into the empyema cavity (fig. 17). Sloughing tissue was removed, and the abscess was packed with gauze impregnated with zinc peroxide. Drainage was maintained by the use of multiple tubes.

Among the first patients received at this center were a number with serious liver abscesses associated with severe bleeding. One patient died. The open method of treatment gave excellent exposure and permitted hemostatic packing of the abscess under direct vision. This technique was lifesaving when bleed-

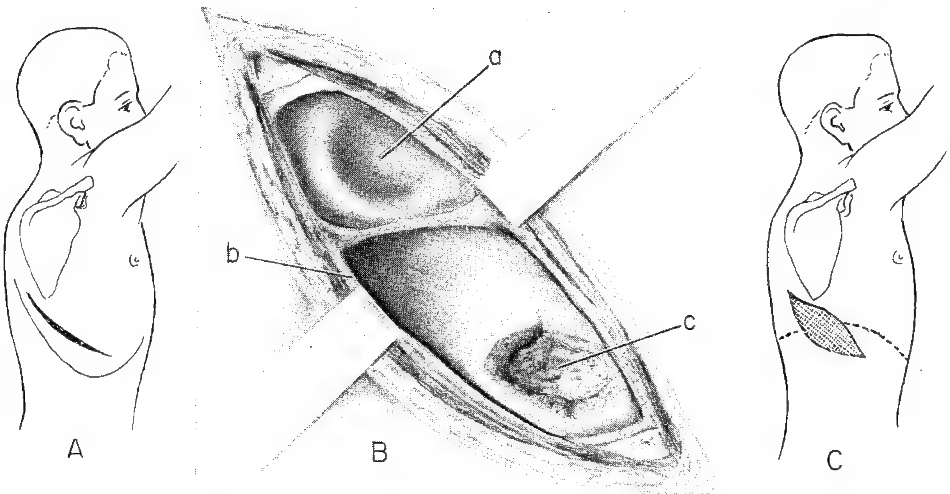

FIGURE 17.—Combined drainage of chronic empyema and liver abscess following thoracoabdominal wound. A. Site of incision. B. Transphrenic deroofing of liver abscess with drainage of liver abscess and localized chronic empyema through same wound: Empyema pocket (a), divided diaphragm (b), and deroofed liver abscess (c). (Performed at 160th General Hospital thoracic surgery center.)

ing was severe, but the duration of healing was intolerably long, and the more definitive procedure was resorted to.

2. If the thoracic component was large, decortication was performed, with repair of the diaphragm and immediate reexpansion of the lung. The hepatic abscess was drained subdiaphragmatically to the point nearest to it on the chest wall.

This technique was first used as a staged procedure in two patients who were acutely ill on admission to the center, with total empyema and large liver abscesses. Both were treated by immediate drainage of the empyema, with deroofing of the liver abscess, followed by subphrenic drainage. Later, when the patients' conditions had improved, decortication was carried out, with closure of the diaphragm. In both cases, convalescence was materially shortened, and the end results were excellent. The procedure was thereafter used routinely, as a one-stage operation.

In one case in which this technique was used, the patient had a liver abscess of 600-cc. volume, a laceration of the diaphragm to which a lacerated lung was adherent, and an 80-percent mixed empyema containing bile. Bile and pus were draining through an 8-inch sucking wound in the third anterior interspace, and over a liter of fluid was being evacuated daily. Wide-open thoracotomy was performed, with decortication of the empyema, repair of the lacerated lung, and lateral drainage of the liver abscess through a liberal rib resection. Drainage of the liver abscess was effected by splitting the dome of the diaphragm wide open to the area of the lateral rib resection. This technique seemed unphysiologic to some observers, who were concerned about the future of the

collapsed lung. The patient, however, was well on the way to recovery when he was evacuated. He was typical of others who responded favorably to similar treatment.

155th General Hospital

Administrative considerations.—The chest center at the 12th Hospital Center was first established at the 90th General Hospital (Hospital Plant No. 4173) on 18 May 1944. On 1 August 1944, the 90th General Hospital was replaced by the 155th General Hospital, which operated as a chest center until it was deactivated on 8 June 1945. Colonel Touroff served as director of the chest center throughout the period of operation. In addition to serving as chief of the thoracic surgery service at the 155th General Hospital, he was responsible for the care of all thoracic casualties in the various medical installations which made up the chest center.[6]

During the 2 weeks between the establishment of the thoracic surgery center and D-day, Colonel Touroff visited all of the hospitals in his hospital center and outlined a plan of treatment for thoracic casualties to the chiefs of the surgical services, who were encouraged to request consultation on all special problems. The policy of referring all elective thoracic surgery to the thoracic center was also inaugurated.

When the center was fully operational and carrying its heaviest load, in the first months of 1945, the personnel, in addition to the director, consisted of three ward officers, six nurses, and five corpsmen. As the ward officers gained in experience, they were able to assume most of the ward work and to relieve the director of many of the routine duties he had originally had to assume himself. Since they had had little surgical training, all major surgical procedures had to be performed by the chief of the center. As the operating load was continuously large, many patients who required extensive secondary closure of superficial wounds or operating procedures confined to the chest wall were transferred to the general surgical section.

Population.—During the operation of the center, 1,388 patients were admitted, of whom 1,252 were referred from other hospitals in the hospital center. In addition, 128 patients were treated in the medical or surgical wards of the 155th General Hospital under the direction of the staff of the thoracic surgery center but were not transferred to it. The director saw 609 patients in consultation in the hospitals of the hospital center and performed 552 major operations. A few of the 836 patients treated by nonsurgical measures required minor surgical procedures, such as secondary closure of small wounds or nerve block.

The greatest patient and surgical load came in February 1945. In spite of the sharp falling off of casualties around V–E Day, admissions to the thoracic

[6] These data are derived from the semiannual reports of the 155th General Hospital for July–December 1944 and January–June 1945, and from a special report on the activities of the chest center by Colonel Touroff on 22 June 1945.

center did not begin to slacken off until the latter part of May, and surgical activity continued into June.

Facilities.—By early November 1944, casualties with chest wounds had become so numerous that they had to be housed in widely separated wards, wherever beds were available. On 11 November, the center was moved into a separate group of three buildings originally designed by the British as a venereal disease section. It continued to function here until the hospital was closed. By the utilization of the services of convalescent casualties, as will be pointed out shortly, the buildings were kept in an excellent state of repair. In the same manner, the grounds were landscaped, rehabilitation facilities were maintained, special equipment and furniture were constructed, and all nonmedical activities of the center were supported.

The thoracic surgery center functioned as a self-contained unit within the 155th General Hospital. Complete facilities were available except for the performance of major surgery, for which the general hospital operating rooms were used. Physical features included accommodations for 165 patients, an operating room for minor surgical procedures and dressings, a recovery ward for postoperative patients, a messhall, a dayroom, a central linen supply room, and adequate office space. Ample grounds surrounding the building were available for rehabilitation activities.

Plan of operation.—The compactness of the unit, an efficient arrangement of facilities, and extensive use of patient labor not only resulted in better care of patients but also effected a great economy in operating personnel. Patients who required maximal medical and nursing care, including bedridden patients and those who needed special medication, were placed in rooms and wards close to the offices for the medical staff and nurses. Here they were always under close supervision. As soon as they became ambulatory or were no longer in need of special attention, they were placed in convalescent wards in which the atmosphere was more that of a military barracks than of a hospital. Noncommissioned officer patients maintained discipline and order. Patients made their own beds and were entirely responsible for the cleanliness and policing of the wards. Convalescence under these circumstances prepared them for subsequent return to duty rather than for prolonged invalidism.

Early mobilization of patients was the rule. As soon as a man became ambulatory, he walked to the operating room for dressings and other treatment. He took his meals in the messhall at the center until he was able to walk to the main messhall in the hospital. These activities not only expedited the return of the patient's strength but also resulted in considerable saving of time and effort on the part of the professional staff and maintenance personnel. Furthermore, the utilization of patient labor made it possible to use the services of medical corpsmen exclusively for medical care.

As part of their program of rehabilitation, patients operated the messhall and linen supply room. They served as clerks, messengers, firetenders, carpenters, painters, and gardeners. Convalescent patients with a special interest in medical work were trained to assist corpsmen on the wards and to help in

the operating room. Others served food to the bedridden patients and to those who took their meals in the messhall of the center.

Equipment.—Equipment at the center was adequate, and every attempt was made to avoid the use of unnecessarily elaborate instruments and accessories. Improvisation was necessary only twice:

1. A new and simple type of bottle stand, for use in closed drainage, was devised, and six were constructed by one of the patients.

2. Extra-long probes, necessary for the packing technique used in certain pleural infections, were also designed at the center and constructed by a patient.

Foreign bodies.—The foreign bodies removed from 318 casualties in the 155th General Hospital chest center are discussed under that heading (vol II, ch. VIII). Included in the discussion is the technique devised at this center for removing certain intrathoracic objects without entering the free pleural cavity.

Suppurative processes.—In 124 cases, the major pathologic process was suppurative, as follows:

1. The infection was intrapleural in 99 cases, 84 of which were managed by open drainage, 13 by decortication, and 2 by closed drainage.

The open-drainage technique included a liberal incision, rib resection, thorough visualization of the interior of the cavity with illuminated retractors, opening of all recesses and loculations, and light packing of the cavity with plain gauze. If the pulmonary surface was rigid and it was thought that reexpansion might be slow, decortication of the lung was carried out within the limits of the visceroparietal adhesions. In none of the 48 cases in which this technique was employed was further revision of the empyema necessary.

The 13 patients selected for primary pulmonary decortication all presented collapse of the pulmonary apex, which was so bound down that a prolonged convalescence seemed inevitable if, indeed, the lung reexpanded at all. In 10 of the 13 operations, healing was by primary union, and the period of postoperative convalescence was greatly reduced. In the three other cases, subsequent open drainage was necessary before cure was accomplished.

The two cases treated by simple closed drainage needed no special comment.

Bacteriologic studies indicated that the type of organism responsible for the pleural infection did not influence the success or failure of decortication. In the two cases in which a culture of pure *Clostridium welchii* was obtained, the course was essentially as benign as in the ordinary pyogenic infection.

2. All four patients with abscess of the lung were treated by a single-stage drainage operation. A small, accurately positioned incision was made directly over the abscess, which was entered through the zone of visceroparietal adhesions invariably present.

In six other cases, pulmonary suppuration was treated by partial lobectomy. In five cases, the lesion was an infected, necrotic hematoma, the result of trauma by high explosive shell fragments. In the remaining case, in which the indication for surgery was continued hemoptysis, the infection, which was caused by Friedländer's bacillus was primary.

3. In each of the three mediastinal abscesses, infection was the result of injury to the esophagus by high explosive shell fragments. In each instance, the suppurative lesion was in the superior mediastinum, above the level of the aortic arch. All three operations were performed in a single stage, through an anterior cervical incision.

4. In five of the eight cases in which empyema and subphrenic abscess were present in combination, drainage was performed through two separate incisions. In the three remaining cases, a single incision was used, the subphrenic abscess being drained by enlargement of the preexistent perforation of the diaphragm.

5. In three of the four subphrenic abscesses, transdiaphragmatic-transpleural drainage was accomplished as a single procedure by the following technique: immediate marsupialization of the diaphragm, by suture, after the pleural cavity had been entered; incision of the diaphragm; evacuation of the subphrenic abscess by suction before spillage could occur; and suture of the edges of the diaphragmatic incision to the margins of the superficial wound, thus further shutting off the free pleura. This procedure, which was devised at the 155th General Hospital chest center, permitted prompt evacuation of a subphrenic abscess without the delay entailed in the usual two-stage procedure. It was of special value in those cases in which the severity of the clinical symptoms made prompt drainage desirable.

In the fourth case in this group, transdiaphragmatic drainage was performed extrapleurally. An incision was made in the costophrenic sinus below the level of the pleural reflection. An incision placed directly over the most superficial portion of the subphrenic abscess provided adequate drainage. It was thought that drainage of the abscess through the empyema cavity would delay healing because of continued contamination from the more highly placed empyema cavity.

Clotted hemothorax.—Decortication was performed in 82 cases of clotted hemothorax, 14 of which were primarily infected. An intercostal incision was used, with division of one rib, or, occasionally, of two ribs, posteriorly. If the parietal membrane was unusually thick and there was considerable restriction and immobility of the chest, the thoracic parietes were decorticated with the lung and diaphragm.

In 2 of the 68 uninfected hemothoraces, a minor postoperative axillary empyema occurred; both processes were drained promptly and obliterated without incident. A small residual axillary empyema was similarly treated in one of the infected cases. Otherwise, the clinical course was the same in both clean and infected cases. In the infected cases, although cultures were positive, the fluid was not grossly purulent. Otherwise, the condition would have been classified as empyema.

Miscellaneous conditions.—Other major procedures consisted of closure of an external esophageal fistula in 1 case, and closure of bronchopleural fistulas, bronchocutaneous fistulas, and large thoracic wounds in 19 cases. They require no special comment.

Fatalities.—Of the four deaths which occurred at the 155th General Hospital chest center, one followed the uncomplicated removal of a superficially situated foreign body and was caused by a cerebral hemorrhage (vol. II, ch. VIII). The other three case histories were as follows:

Case 1.—This patient sustained a perforating wound of the trachea and a compound comminuted fracture of the mandible, due to high explosive shell fragments. At the time of wounding, there was considerable aspiration of blood into the tracheobronchial tree.

The patient was admitted to the chest center about 2½ weeks after wounding, because of extensive pulmonary suppuration in the right lung and a mediastinal abscess. Temporary improvement followed drainage of both abscesses. About 10 days later, there was evidence of further spread of the gangrene, and death soon followed. Post mortem showed the cause of the fatality to be septic thrombophlebitis of the pulmonary vein, anaerobic septicemia, and multiple metastatic abscesses.

Case 2.—This patient sustained a right-sided bullet wound which involved the liver, right diaphragm, lung, chest wall, and brachial vessels. He was received in the chest center after amputation of the right arm, drainage of an extensive hepatic and subphrenic abscess, and secondary laparotomy for acute intestinal obstruction. At this time, he had a chronic empyema, with a right-sided bronchopleural fistula. He was extremely emaciated, and a substantial excavation within the liver, with a complete external biliary fistula, was evident through a large gaping wound in the right upper quadrant. Laboratory tests revealed material reduction in liver function.

Drainage of the pleural infection was followed by prompt subsidence of toxic manifestations, but the patient presented serious nutritional problems, and death occurred 3 weeks after operation, after a progressively downhill course. Post mortem revealed extensive chronic hepatocellular damage, diffuse biliary cirrhosis, and atrophy of the liver.

Case 3.—This patient sustained a thoracoabdominal wound on the left side, which was followed by pleural infection, diffuse fibrinopurulent plastic peritonitis, and multiple intra-abdominal abscesses. Neither thoracotomy nor laparotomy had influenced the septic course, and he was admitted to the center for revision of the inadequately drained empyema. Death occurred after the secondary drainage operation and was attributed at post mortem to intraperitoneal suppuration with multiple encapsulations of pus throughout the abdomen, not amenable to surgical treatment.

Results.—Evaluation of the results of therapy was not possible because of the short time the patients were under observation. In most instances, those who did not require evacuation to the Zone of Interior were sent to rehabilitation and reconditioning centers to be prepared for return to duty.[7]

Rehabilitation.—As is evident from what has already been said, the rehabilitation program at this chest center required the participation of convalescent patients in all of the activities of the center. This was an efficient and wholesome way of expediting their recovery, and the sight of these recently wounded men working about the wards and in other parts of the hospital, as well as on the grounds, was a continuing source of encouragement to newly arrived patients, who realized hopefully that they too would soon be on the road to recovery.

The rehabilitation program as such was carried out under the direct supervision of a designated officer patient, assisted by other convalescents. It con-

[7] Several attempts were made in the European theater to follow up patients by means of postcards which accompanied the patient to the rear and were preaddressed to the surgeon who had treated him in the forward hospital. None of these attempts was successful in a sufficient number of cases to permit an analysis of results.

sisted of general physical exercises; special thoracic exercises; exercises designed to restore the function of specific muscles, especially those of the shoulder and upper arm; and graded competitive sports.

As soon as a patient arrived in the center, he was given written and personal instruction in thoracic exercises, which were engaged in by all patients, whether ambulatory or bedridden, under supervision, at least three times a day. Individual exercises were prescribed as necessary. Early mobilization was encouraged, and most patients were out of bed on the second or third day after operation. As the patients regained their strength, they were encouraged to participate in outdoor athletic activities, such as horseshoe pitching, badminton, volleyball, and basketball. The volleyball and basketball courts were constructed by the patients as part of their own advanced rehabilitation activities. Competitive activities were graded from mild to strenuous, and patients were permitted to indulge in them as their strength increased.

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CHAPTER V

Administrative Considerations in the Zone of Interior

Brian Blades, M.D., B. Noland Carter, M.D., and Michael E. DeBakey, M.D.

When the United States entered World War II, thoracic surgery was not yet a fully developed specialty. The American Association for Thoracic Surgery, stimulated by the advances in the specialty in World War I, had been formed in 1918, but The Board of Thoracic Surgery, Inc., was not set up until 1948. The amount and variety of thoracic surgery performed at the various chest centers overseas and in the Zone of Interior provided a stimulus that took this specialty out of tuberculosis sanatoriums and initiated its postwar advances.

THE CONSULTANT IN THORACIC SURGERY

No consultant in thoracic surgery was ever formally appointed in any oversea theater during World War II, probably because of the still uncertain status of this specialty at the beginning of the war. In the Zone of Interior the situation, fortunately, was different. In July 1942, Capt. (later Col.) Brian Blades, MC, was assigned to Walter Reed General Hospital, Washington, D.C., with the specific mission of setting up a thoracic surgery service. Shortly afterward, he was appointed Consultant in Thoracic Surgery, Office of The Surgeon General, and he served in both positions until the end of the war.

When Captain Blades assumed his duties at Walter Reed General Hospital, there was no thoracic surgery service there or at any other hospital in the Army system. At Walter Reed General Hospital, however, thoracic surgery had a status of sorts. This was chiefly because of the continuing influence of Col. William L. Keller, MC, who, almost singlehandedly, had cleaned up the backlog of chronic chest infections that were the heritage of World War I. His work was so brilliant that the most eminent chest surgeons of the day came long distances to observe it.

The connecting link between Colonel Keller and the thoracic surgeons who came to Walter Reed General Hospital in the first months of World War II was Col. (later Maj. Gen.) Norman T. Kirk, MC, who had served under

Colonel Keller and who had maintained his interest in chest surgery after the latter retired.

Incidentally, it was the vivid recollection of the chronicity of those World War I infections and the length of time—almost 10 years—it had taken to dispose of them that made General Kirk, then The Surgeon General, so unwilling to release thoracic surgeons from service at the end of World War II.

In July 1942, when Captain Blades assumed his duties at Walter Reed General Hospital, there were not more than a dozen civilian clinics and centers in the United States at which thoracic surgery was being done as a separate specialty or in any volume. Some tuberculosis surgery was being done at Fitzsimons General Hospital, Denver, Colo., but at the Walter Reed General Hospital, chest surgery was chiefly limited to the type being done just after World War I. In September 1942, when Captain Blades did the first pneumonectomy performed at any Army hospital, it was characteristic of the opinion then held of the operation that there was considerable disapproval of his boldness in undertaking it. The patient, fortunately, made an excellent recovery.

By the time the first casualties arrived from North Africa, late in 1942, the thoracic surgery service, which had originally shared a ward with the neurosurgical service, had its own ward and its own personnel. In March 1943, Walter Reed General Hospital was designated as a thoracic surgery center (p. 171), and as such it continued to expand until the end of the war. It is interesting to recollect, since it was the first thoracic surgery center to be designated in World War II, that it had served the same purpose in World War I, under Colonel Keller's direction.

In his capacity as Consultant in Thoracic Surgery to The Surgeon General, Captain Blades responded to requests for advice from that office or offered advice himself as the situation demanded. Relations between himself and the personnel of the Office of The Surgeon General were always cordial and close. General Kirk, as already mentioned, had a special interest in thoracic surgery because of his association with Colonel Keller, and with Maj. (later Col.) Michael E. DeBakey, MC, and Lt. Col. (later Col.) B. Noland Carter, MC, of the Surgical Consultants Division, who had practiced this specialty in civilian life. There was therefore a meeting of minds on policies and practices.

One of Captain Bladies' duties as Consultant in Thoracic Surgery to The Surgeon General was the inspection of thoracic surgery centers. Each of these centers was visited at 3- or 4-month intervals during the war, and occasionally, if special problems required solution, they were visited oftener. This necessity, however, was not usual. All of the centers were directed by well-trained and experienced thoracic surgeons, and while there were sometimes differences of opinion about details, there was practically always complete agreement upon principles.

SUBCOMMITTEE ON THORACIC SURGERY, DIVISION OF MEDICAL SCIENCES, NATIONAL RESEARCH COUNCIL

The Subcommittee on Thoracic Surgery was one of the numerous subcommittees formed by the Division of Medical Sciences, National Research Council, to act in an advisory capacity to the Surgeons General of the Army, Navy, and Public Health Service (*1*). Its membership consisted of Dr. Evarts A. Graham, Chairman, Dr. Isaac A. Bigger, Dr. Edward D. Churchill, Dr. Leo Eloesser, Colonel Keller, Col. (later Brig. Gen.) Charles C. Hillman, MC, Capt. (later Col.) James H. Forsee, MC, and Comdr. (later Rear Adm.) Frederick R. Hook, USN (MC).

The general functions of the Subcommittee on Thoracic Surgery were to give advice on the organization of hospitals from the standpoint of thoracic surgery, on the care of thoracic wounds, and on any other phases of thoracic surgery on which advice might be required. This Subcommittee was also to consult with the Subcommittee on Anesthesia, National Research Council, which was organized a little later, and to prepare a small manual on thoracic surgery. Work on this manual had already begun (p. 167) when the Subcommittee was organized.

The Subcommittee on Thoracic Surgery held two meetings, the first on 25 July 1940 (*1*), before the United States entered the war, and the second on 16 January 1942 (*2*), some six weeks after Pearl Harbor. At both meetings, the chief discussions concerned thoracic surgery personnel, and at the first, the general point of view seemed somewhat unrealistic, the chief dissenter being Colonel Keller. Contrary to the views of most of those present, he doubted that the supply of trained thoracic surgeons would be in any way adequate to the demand. In his opinion, therefore, these surgeons should be carefully assigned and employed only in the largest installations, where they could be utilized to their full capacity. He repeatedly emphasized that the more generous assignments visualized by the other members of the Subcommittee must be regarded as tentative. By the second meeting, others had come to share Colonel Keller's views.

It is a great pity that the potentialities of the Subcommittee on Thoracic Surgery were not utilized as they might have been. There was no real liaison between it and the operating personnel responsible for thoracic surgery in the Office of The Surgeon General. Some of its members, particularly Dr. Graham and Colonel Keller, had had extensive military experience in World War I, and this experience might have been of great value, and prevented many errors, if it had been properly utilized in World War II. In retrospect, it almost seems that the Subcommittee met and made its suggestions in a vacuum. Certainly its advice did not reach the quarters in which it might have been useful.

PERSONNEL

By 1938, the American Association for Thoracic Surgery, which had been formed in 1918, had 14 honorary members, 99 active members, 69 associate members, and 30 senior members. It was from the group of active and associate members that the thoracic surgeons who served as directors of thoracic surgery centers, as heads of thoracic surgery services, and as members of thoracic surgical teams were chiefly drawn; they numbered 168. As already pointed out, The Board of Thoracic Surgery, Inc., was not founded until after the war, and the reservoir of qualified specialists provided by diplomates of other boards thus did not exist for thoracic surgery.

One of the more useful actions of the Subcommittee on Thoracic Surgery was to group the membership of the Association, on the basis of their qualifications, for the use of The Surgeon General in assignment, as follows (*2*):

Class I, capable of being a consultant in thoracic surgery.

Class II, capable of being the chief of the thoracic surgical service in a large hospital.

Class III, capable of being an assistant chief of the thoracic surgical service in a large hospital or chief of service in a small hospital.

Class IV, capable of being a ward officer or assistant ward officer on a thoracic surgery ward.

On Dr. Churchill's suggestion, a supplementary list of thoracic surgeons was obtained by writing to all the surgeons in classes I and II and requesting them to submit the names of young surgeons who had received all or part of their training in thoracic surgery under their supervision within the last 5 years.

Early in the war, the assignment of thoracic surgery personnel was far more difficult, and far less satisfactory, than it should have been because the Personnel Division, Office of The Surgeon General, made assignments arbitrarily, without full knowledge of the capabilities and experience of the specialists involved, and without consultation with the Surgical Consultants Division, Office of The Surgeon General. As a result, there were some wasteful misassignments. A medical officer, for instance, born in China and speaking Chinese, requested an assignment for thoracic surgery in the China-Burma-India theater, where his peculiar combination of abilities would have made him most useful. He was assigned to making physical examinations in the North Atlantic Patrol, and it required almost a year to change his assignment.

Eventually, after about a year of difficulty, The Surgeon General issued an order that no assignments were to be made in the surgical specialties without the approval of the Surgical Consultants Division of his office. It was still necessary, as it was to the end of the war, to locate thoracic surgeons by personal contact with the heads of civilian services, but at least the misassignments made early in the war were practically ended.

The Consultant in Thoracic Surgery was, of course, consulted by the Surgical Consultants Division on all personnel assignments and was of great help in making them.

TRAINING

The possibilities of training in thoracic surgery were considered at the first meeting of the Subcommittee on Thoracic Surgery, Division of Medical Sciences, National Research Council, in July 1940 (*1*). The question had already been discussed by the parent Committee on Surgery, with special reference to the training of Reserve officers, but nothing had been done because of lack of funds.

It was the opinion of the Subcommittee that more thoracic surgeons should be trained, and all who were present at the meeting expressed themselves as glad to assist if funds could be made available. There were, however, fundamental differences of opinion as to the courses to be set up. Colonel Hillman thought that they should not be longer than 2 weeks. Dr. Graham thought that nothing desirable could be accomplished in less than 2 or 3 months.

Training was again discussed when the Subcommittee met on 16 January 1942 (*2*). There was general agreement that it was feasible to train thoracic surgeons for the Army in civilian hospitals. Dr. Churchill displayed a map of the United States on which he had designated certain large civilian clinics which could provide the necessary facilities and personnel. Three months was considered the minimum length for the courses, and Dr. Churchill thought that, in certain instances, officers assigned for this training might be of greater eventual value to the service if they were retained for longer periods of instruction. It was agreed that officers assigned to these courses should be selected most carefully. If they proved unsuitable for the work, or if they did not apply themselves, the Office of The Surgeon General would be notified at once and they would be relieved from the assignment.

The Subcommittee agreed to advise The Surgeon General shortly of the availability of courses in thoracic surgery in civilian institutions which could be attended by medical officers.

The courses were set up at Columbia University, New York, N.Y., The University of Michigan, Ann Arbor, Mich., the University of Pennsylvania, Philadelphia, Pa., and Washington University, St. Louis, Mo. Like the similar courses in neurosurgery, these intensive courses proved a very satisfactory way of providing intensive training in thoracic surgery for men who already had some training in general surgery. In the beginning, the selection of students was not handled as wisely as it might have been. Those selected did not always have a background of general surgery, and it was sometimes difficult to see on what basis they had been chosen. Inappropriate volunteers were also permitted. Eventually, these difficulties were straightened out, and the end results were excellent. The majority of the graduates were sent overseas, where many of them rendered outstanding service in various capacities in thoracic surgery

centers and on thoracic surgery services. A few were retained in this country. It is interesting to note that one or two of the most outstanding graduates had begun this course with great reluctance and with no interest at all.

In spite of the casual fashion in which students for these courses were originally selected, the instruction was frequently of great value from the standpoint of the medicomilitary effort. Sometimes, in addition, it had a great impact upon the careers in service and the future medical careers of some of the students. The following letter from Dr. (formerly Maj., MC) David J. Dugan, written in response to an inquiry concerning his instruction at the University of Pennsylvania, makes this quite clear. Dr. Dugan wrote, in part, as follows:

My enrollment in the thoracic surgery course at the University of Pennsylvania was entirely unsolicited. I was doing general surgery in Cleveland before I entered the service in September 1942. I was assigned to Walter Reed General Hospital, but as soon as I arrived I received orders to report to the University of Pennsylvania to take a course in thoracic surgery, a specialty I barely knew existed. There were nine in the class. At the same time, courses were being given there for medical officers in neurosurgery and in surgery of the extremities. Both courses, as I recollect, had enrollments of 30 to 35 officers. Thoracic surgery was certainly in the minority.

The object of all these courses was to train general surgeons in these particular specialties, so that they would have additional knowledge and experience when they were sent overseas, which, we understood, would be as soon as the courses were completed.

The thoracic surgery course lasted for 6 weeks. There were daily lectures, from 8 to 12, attended by the men in all three courses, and given by physiologists, biochemists, and anatomists. They were very general, and much of the time was spent on antibiotic therapy, then very new. These lectures were excellent.

In the afternoons, the students in the thoracic surgery course went to the various hospitals in Philadelphia, particularly to observe endoscopic work. We had no practical experience, but we did have the opportunity to observe such men as Clerf and Chevalier Jackson while they were at work. We also operated on cadavers in the afternoons, an experience I found very valuable, for we worked under the supervision of Dr. Batson, then Professor of Anatomy at the University of Pennsylvania, who had a remarkable ability to combine the academic and clinical aspects of anatomy. It was a real privilege to study anatomy under him.

An examination was given at the end of 6 weeks, and while none of us, so far as I know, ever found out how we had done, we all had the impression that our grades would determine how far away from home we would be sent. Whether that rumor was true I never found out.

At any rate, at the end of the course, I was sent back to Walter Reed. Almost as soon as I arrived, a large convoy of chest casualties was received, and my only qualification for assisting in their care was the 6 weeks' course I had just completed. Fortunately, my work was done under the supervision of Colonel Brian Blades, who was in charge of the thoracic surgery service at Walter Reed throughout the war.

I worked under Colonel Blades for the next 3 years, then was put in charge of the thoracic surgery service at Fitzsimons General Hospital in Denver until I was separated from service in September 1946.

The course at the University of Pennsylvania, although it was a totally unexpected introduction to my Army service, was a real delight and completely altered my medical career. When I left the Army, I came to Oakland, Calif., and I have been engaged here since in the private practice of thoracic surgery.

ANESTHESIA

Anesthesia for intrathoracic surgery was generally satisfactory at the beginning of the war, since competent anesthesiologists, equipped to give intratracheal anesthesia, were available in all hospitals in which such surgery was done. It became increasingly satisfactory as the war progressed, as anesthesiologists gained experience, and as more of them became available through formal and informal training.

Equipment for anesthesia was uniformly good. Dr. Joseph Kreiselman, Consultant in Anesthesia to The Surgeon General, was of great assistance in the selection of the most efficient equipment for special techniques as well as for general techniques.

EQUIPMENT

The thoracic surgery equipment which Captain Blades found when he assumed his duties at Walter Reed General Hospital in July 1942 was chiefly that used for the operations performed after World War I. These deficiencies were shortly corrected by provision of the list of supplemental instruments drawn up by Dr. Eloesser and Colonel Kirk (*2*), which were supplied to all hospitals. As a matter of fact, most thoracic surgery was then—and still is—done with the instruments used in general surgery, and these were in ample supply.

Instruments for thoracic surgery were eventually of the highest quality and were provided in sufficient numbers, though those used by the hospitals supporting the North African invasion in November 1942 were deficient in both quality and quantity (p. 84). Part of Captain Blades' duties as Consultant in Thoracic Surgery to The Surgeon General concerned the revision of the lists of thoracic surgery equipment.

MANUAL ON THORACIC SURGERY

The work of the Subcommittee on Thoracic Surgery on a manual on this subject was initiated 10 July 1940, when Colonel Hillman, Chief, Professional Service Division, Office of The Surgeon General, notified Dr. Graham that among the technical manuals which his office considered necessary was one on thoracic surgery. He requested that Dr. Graham submit to him a list of subjects that should be covered in such a text.

Two weeks later, when the first meeting of the Subcommittee was held (*1*), a considerable start had been made on this book. The members of the Subcommittee were asked to study and comment on the 40 pages already prepared, and Dr. Eloesser, who had worked on the material with Dr. Graham, displayed a chart that tabulated the material to be included in the text and which was suitable for use in operating rooms.

In discussing the manual at this meeting, Colonel Hillman stated that he wished the book to be loose-leaf, to be very brief, and to cover the treatment of chest injuries only from wounding until the casualty reached an evacuation hospital. The book was not to include definitive treatment, since the medical officers responsible for that phase of therapy would not need such a book. Colonel Hillman thought that a list of texts should be included. It was his idea that the manual be distributed only to medical officers responsible for first aid; the expense of a wider distribution would be too great.

Shortly before this meeting, Dr. Graham had written Colonel Hillman that the preparation of this manual had become more complex than he had anticipated. The final revision was not accomplished until the meeting of the Subcommittee on Thoracic Surgery on 16 January 1942 (*2*), when both the text and the illustrations were approved. By this time, the original concepts had been altered in a number of respects. The manual, which is described in detail elsewhere (p. 190), did not appear until 1943 (*3*), and did not play the role that had been visualized for it.

THORACIC SURGERY CENTERS

Historical Note

In World War I, certain hospitals were staffed and equipped by the Medical Department for the care of special groups of casualties. There were no thoracic surgery centers, as might have been expected. At that time, few surgeons were qualified in this specialty or interested in limiting their activities to diseases and injuries of the chest. In a few hospitals, suppurative pleuritis was segregated, but the patients with this condition were usually cared for on septic surgery sections. In any event, segregation went no further.

In the interval between the World Wars, a limited amount of specialization became the policy in Army hospitals, but it was chiefly confined to radiology and neuropsychiatry. If specialized surgery was required, it was provided by civilian surgeons working under contract.

Evolution of Policies

In 1939, when planning began for the war that seemed imminent, changes in the tables of organization of hospital units began to reflect the civilian tendencies toward increased specialization (*4*). New tables published during 1940 listed, for the first time, the specialists required to serve as chiefs of professional services and as ward officers. These tables also allotted to hospitals more enlisted men with specialist ratings and correspondingly fewer with only basic military training. The total number of officers and enlisted men assigned to hospitals was also increased. In a 1,000-bed general hospital, for instance, the number of officers was increased from 42, of whom 30 were medical officers,

to 73, of whom 55 were medical officers. The number of enlisted men assigned to such a hospital was also increased, from 400 to 500.

As increasing numbers of specialists in various fields entered the Army, civilian emphasis upon specialization began to be reflected in Army policy. By the end of 1942, The Surgeon General made it clear that he intended to formalize and extend this policy. The circumstances were ripe for his action.

By this time, new general hospitals were beginning to open one after another, and it was soon clear that the limited supply of specialists in various fields would not be sufficient to permit the staffing of each of them for all varieties of medical and surgical work. At the same time, with the transition from defensive to offensive warfare which occurred with the invasion of North Africa, the Medical Department was obliged to visualize the arrival in the Zone of Interior of increasingly large numbers of combat casualties who would require specialized treatment. The plan of specialized centers therefore began to take shape.

There was, however, a serious obstacle to its implementation. In the fall of 1942, there was growing public insistence that casualties should be hospitalized as near as possible to their homes, and in December of that year, The Adjutant General proposed the establishment of hospitalization policies to meet this demand. If these policies had been adopted and applied rigidly, they would have conflicted with The Surgeon General's (still unpublicized) plan to transfer casualties who required specialized treatment to hospitals specializing in the treatment of particular diseases or injuries.

The Surgeon General proposed to resolve the conflict in two ways:

1. By sending patients who needed specialized treatment to general hospitals designated to supply such treatment.
2. By sending those who required prolonged, but not specialized, treatment to hospitals in the vicinity of their homes.

This policy was announced on 1 February 1943. For the next several weeks, the Hospitalization and Evacuation Division, Office of The Surgeon General, worked on the problem, and on 6 March 1943, upon their recommendation, the War Department designated 19 general hospitals for the treatment of 6 specialties, including chest surgery.

In 1939, only two hospital centers were conceived of in the medical planning,[1] and until the middle of 1944, specialty centers in general hospitals were established piecemeal, to meet needs as they arose, without regard to eventual requirements. Up to this time, too, the beds allotted for specialized treatment in general hospitals occupied only a small proportion of the total hospital bed capacity.

[1] At the first meeting of the Subcommittee on Thoracic Surgery, there had been some discussion about concentrating casualties with thoracic injuries in specialized hospitals, but the plan was not then considered practical.

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There were at least two reasons for this chaotic situation:

1. An army in training, which the U.S. Army was, for the most part, in the first months of the war, had less need for specialized services than an army in combat.

2. Early in the war, it was difficult to predict the types and amounts of specialized care that would be needed. In the summer of 1944, the Facilities Utilization Branch, Office of The Surgeon General, engaged in a study of the anticipated need for specialized centers and the preparation of a comprehensive plan to meet it. By the time of the invasion of Europe, enough casualties had been received from the North African theater and from the Pacific to permit the breakdown of the anticipated casualty load in terms of wounds, injuries, and diseases.

The general features of this plan, which were announced in War Department Circular No. 347, issued on 25 August 1944, remained in effect throughout the war. They were as follows:

1. As far as practical, related specialties were grouped in the same hospital centers, in order to improve the quality of professional care.

2. Attempts were made to locate centers for specialized treatment in relation to population density, to permit the utmost compliance with the policy of hospitalizing patients as near their homes as possible. Success in this respect was limited by several considerations. One was the uneven initial distribution of hospitals: there were proportionately fewer hospitals in the densely crowded areas of the northeastern United States than there were in the South and Southwest, where, logically, they had been located to serve large concentrations of troops in training. Another reason for difficulty in hospitalizing patients in need of specialized care was that all specialties did not require the same number of centers. Neurosurgical and orthopedic casualties, for instance, required provision for many times the numbers of beds required for blinded and deafened casualties.

There was some disagreement concerning the most useful size for the centers. Professional consultants in the Office of The Surgeon General preferred that they be kept reasonably small. The Facilities Utilization Branch in that office considered it more economical to limit the number of centers and increase their size, in view of the increasing shortage of specialists, which required them to be so assigned that they could be utilized to the fullest.

As the patient load increased, much of this argument became academic. In the last months of the war, some centers had 2,000 or more beds, and in a number of instances, general hospitals became, in effect, specialized hospitals. When the peak of the patient load in the Zone of Interior was reached, in June 1945, there were 234 centers for treatment of the various specialties, located in 65 hospitals, and with a total of 132,178 beds.

Operation of hospital centers for thoracic surgery in the Zone of Interior was attended with all the advantages of their operation in oversea theaters (p. 98). In addition, these centers offered unusual opportunities for the

study of diseases of the chest, many of which are seen in too small numbers in civilian practice to permit conclusions as to their management.

Thoracic surgery centers also had another highly practical advantage. The strict regulations that required patients in need of thoracic surgery to be sent to them kept surgeons untrained in this specialty from performing operations for which they were not qualified. This was an important consideration at a time when thoracic surgery was still a developing specialty.

Location of Centers

Four thoracic surgery centers were designated on 6 March 1943, at Walter Reed General Hospital, Fitzsimons General Hospital, Kennedy General Hospital, Memphis, Tenn., and Hammond General Hospital, Modesto, Calif. Within a short time, it was evident that these four centers would be unable to handle the anticipated patient load, and in May 1943, Brooke General Hospital, San Antonio, Tex., was also designated as a center for thoracic surgery. Bruns General Hospital, Santa Fe, N. Mex., although it was never formally designated as a chest center, received most casualties with tuberculosis who required surgery and also received a small number of patients who required chest surgery for other reasons.

In August 1944, Baxter General Hospital, Spokane, Wash., was designated as a chest center, to replace the center at Hammond General Hospital. In July 1945, consideration was given to relocating the center at Walter Reed General Hospital, partly for administrative reasons and partly because a thoracic surgery center was needed in the northeastern United States. Halloran General Hospital, Staten Island, N.Y., was recommended for this purpose, but the Hospital Planning Division did not agree, and the chest center at Walter Reed General Hospital was maintained even after other chest centers were closed.

Facilities and Equipment

Some thoracic surgery centers occupied existing facilities throughout the period of their operation. At Fitzsimons General Hospital, for instance, active surgical patients were treated in two wards of 163 beds, with 23 of the 196 beds assigned to the chest service reserved for tuberculosis surgery. Ambulatory convalescent patients were cared for in outlying wards while awaiting ultimate disposition.

At Baxter General Hospital, the special facilities constructed for the chest center were not ready until 1 October 1945. They included offices for the director of the center and his assistants, conference rooms with view boxes, a recovery ward for postoperative patients (with provision for bedside oxygen and negative pressure suction), a complete roentgenologic and fluoroscopic unit, a central dressing room for ambulatory patients, an operating room for minor surgery and bronchoscopy, and kitchen facilities for the postoperative recovery ward.

After the first months that the centers were operated, instruments and other equipment were generally both excellent and plentiful. There were, however, occasional exceptions. Thus in March 1945, the center at Baxter General Hospital still had no Heidbrink anesthetic machines, which were urgently needed for efficient intratracheal anesthesia. Intratracheal anesthesia could be given with the equipment available, but patients would have been anesthetized more safely and more easily had the proper specialized equipment been provided.

Policies and Practices

As part of the planning for special centers in the summer of 1944, Brig. Gen. Fred W. Rankin, Chief Consultant in Surgery, Office of The Surgeon General, wrote to the Chief, Personnel Service, in the same office, that for a thoracic surgery center of 350 beds, he considered that minimum personnel should consist of a chief of service, an assistant chief, and two ward officers. This minimum was always met, in spite of the shortages of thoracic surgeons, and on busy services, it was frequently exceeded.

When the thoracic surgery center at Baxter General Hospital was opened, a medical consultant with wide experience in diseases of the chest was assigned jointly to the medical service and the thoracic surgery center, as liaison officer. This greatly facilitated consultation procedures. Similarly close liaison was established with the Radiology Section by the appointment of a junior officer to work on both services. At daily conferences, all newly taken roentgenograms were jointly reviewed by the roentgenologist, the staff of the surgical center, and the liaison officers. Treatment was facilitated and its quality greatly improved by these conferences, which, in one form or another, were held at all centers.

A certain proportion of the patients assigned to chest centers, averaging about 20 percent, required consultation with, and treatment by, other specialists. This was especially true of casualties with neurosurgical and orthopedic injuries. No time was lost in seeking these consultations, and the turnover of beds was rapid. At the Fitzsimons General Hospital chest center, the average period of hospitalization was less than a month.

Clinics for diagnostic procedures, and, occasionally, for therapeutic procedures, were an important phase of the work of all centers. In 1944, the clinic at Fitzsimons General Hospital carried out 1,665 such procedures, including 35 laryngoscopies, 474 bronchoscopies, 52 gastroscopies, 513 fluoroscopies, 23 esophagoscopies, 462 bronchographies, 71 other installations of contrast media, and 35 dilatations of the esophagus.

Associated Convalescent Hospitals

When convalescent hospitals were first opened in the Zone of Interior in 1944, they were frequently established on the same posts as general hospitals. At first, most of them were administered under separate commands and with

a separate administrative organization for the control of patients and all other activities. Later, convalescent hospitals were operated as hospital centers, a policy which had a number of advantages. Under it, the administration, supply, and service activities of both installations were carried out in a single headquarters, which freed hospital commanders of much administrative detail, reduced personnel, and eliminated duplicating and overlapping effort.

Centralization also made it easier to shift personnel between the hospitals and the convalescent centers as they were needed. One of the chief advantages was the operation of a single registrar's office for both installations. This made it possible to move patients from one to the other by simple internal transfer rather than by the complicated procedures necessary when they were moved between separate installations.

The thoracic surgery centers began to close before final plans for the most efficient operation of the convalescent hospitals in connection with them could be put into effect.

REPORTS OF THORACIC SURGERY CENTERS

The methods of operation and the experiences of the thoracic surgery centers in the Zone of Interior varied in details, but policies and practices were much the same in all. The experiences of the Kennedy General Hospital thoracic surgery center during the war and of the Walter Reed General Hospital thoracic surgery center after the war are presented as typical.

Kennedy General Hospital

Population.—The chest surgery service at Kennedy General Hospital began in June 1943, with a few patients in a single ward.[2] At the end of the year, the service had an average census of 40 patients. By the end of 1944, it had spread to five wards, and the average daily census was more than 400. During 1944, 721 of the 6,237 hospital admissions were to the thoracic surgery service. During 1945, when the capacity of the center was 350 beds, 2,268 of the 12,813 hospital admissions were to the center. During this same year, 1,502 of the 6,010 operations performed were for chest conditions; the figures include 833 endoscopies.

Personnel.—Lt. Col. Richard H. Meade, MC, was in charge of the chest service at Kennedy General Hospital from its inception until 1 December 1945. The medical officers originally assigned to the center, who remained for varying lengths of time, had had no training in chest surgery with a single exception, Capt. William I. Glass, MC. Maj. (later Lt. Col.) Felix A. Hughes, Jr., MC, who had a good background in thoracic surgery, was attached to the center on 22 July 1944. At various times thereafter, a number of other experienced chest surgeons arrived, including Maj. (later Lt. Col.) Earle B. Kay, MC, who had headed the chest service at Percy Jones General Hospital,

[2] This report was prepared by Lt. Col. Richard H. Meade, MC, in December 1945.

Battle Creek, Mich.; Capt. Lawson S. Whitaker, Jr., MC, who had had a wide experience in the South Pacific; Capt. Joseph Estrin, MC; Maj. Theodore R. Hudson, MC; and Maj. Julian Johnson, MC, who had previously been assigned to the China-Burma-India theater.

The center was most fortunate in the ward officers, the nurses, and the technicians assigned to it. The ward officers included Capt. William B. Blake, Jr., MC, Capt. (later Lt. Col.) Prince D. Beach, MC, Capt. Max A. Forse, MC, and Capt. Henry G. Mundt, Jr., MC. Captain Blake and Captain Beach assisted in the operating room, in addition to their ward duties. Captain Forse and Captain Mundt for a long time had charge of the wards through which the patients passed who needed little treatment; they kept the rate of disposition on these wards at a very high level. Nursing care was under the supervision of Lt. Alison Bolyea, ANC. T. Sgt. Samuel P. Crucilla was in charge of dressings and also handled intravenous therapy for all critically ill patients.

Additional personnel were assigned to the Kennedy General Hospital thoracic surgery center, chiefly for training purposes. They included medical officers from Lawson General Hospital, Atlanta, Ga., from 1 January to 3 March 1944; from the 141st General Hospital, which was stationed on the reservation from 1 January to 10 June 1944; and from the 4th Auxiliary Surgical Group, surgeons from which were assigned to the center on detached service.

In spite of the help furnished by these officers, the ratio of patients to officers was usually undesirably high. It required unceasing effort to keep the backlog of operations and dispositions under control.

Organization and operation.—Patients were received in the center from overseas, from other hospitals in the country, and from other services at the Kennedy General Hospital. Each week, at a special conference of the staff of the center, all new patients were discussed, and the problems that concerned them and other patients were worked over and settled. The staff of the center had excellent cooperation from all other services in the hospital.

In addition to the wards occupied by bed patients, the center had other space which could be designated for such special purposes as they wished. Until late in 1944, operations were done in the general operating rooms. Thereafter, the center had its own operating room.

While battle casualties accounted for most admissions to the center, the majority of the surgical work performed was for conditions unrelated to warfare. After his assignment, all lesions of the esophagus were handled by Major Kay. The remainder of the surgery was quite evenly distributed among the other thoracic surgeons.

Battle casualties.—Up to December 1945, more than 1,950 patients with battle wounds had been admitted to the center. The great majority had been so well treated overseas that they required little major surgery. The principal treatment necessary was maintenance of previously established drainage of empyema. The distribution of cases was as follows:

1. Of 113 patients with chronic empyema, 99 had sustained combat wounds. Of these, 76 were treated by drainage, 28 by decortication, and the remainder by some form of thoracoplasty.

2. Of 113 patients who had had decortications overseas, 91 had healed wounds when they were admitted. The remaining 22 had empyema or had draining wounds which required treatment.

3. In all, 64 operations were done for the removal of foreign bodies. Only those objects were removed that were more than 1 cm. in diameter; were giving rise to symptoms; were irregular; or were in contact with the esophagus or with some other structure that, it was feared, might be damaged by the contact.

4. A number of patients had defects of the chest wall, but operation was done in only five cases, in which the location of the defect introduced elements of danger. In two instances, the defect was over the heart, and the soft tissues were adherent to the pericardium; in both cases, the insertion of a protective plate was thought safer than an attempt at plastic repair.

5. The majority of the 21 operations for diaphragmatic hernia were done for residua of perforating wounds of the diaphragm or crushing injuries. Several of these hernias, which are discussed in detail elsewhere (vol. II, ch. IV), were not apparent until several months after the original injury.

6. The 19 patients with lung abscess were all treated by drainage and all recovered.

7. The single patient with suppurative pericarditis was treated by drainage and penicillin and recovered smoothly.

Non-combat-incurred lesions.—Operations for civilian-type thoracic lesions at Kennedy General Hospital were distributed as follows:

1. The most frequent disease for which surgery was required was bronchiectasis, for which 129 lobectomies were done, with 1 death. These lobectomies are analyzed in detail elsewhere (vol. II, ch. X). Two total pneumonectomies were also performed for bronchiectasis.

2. The next most frequent indication for lobectomy was pulmonary cysts, for which 14 operations were done. Other indications included tuberculosis in two cases, on the mistaken diagnosis of infected cysts; bronchial adenoma (two cases); chronic suppurative lesions which did not respond to simple drainage (three cases); and actinomycosis (one case). There were no deaths in these 22 operations.

3. In addition to the 2 pneumonectomies already mentioned for bronchiectasis, this operation was performed in 14 other cases, for bronchial adenoma (6 cases, in 1 instance malignant); for carcinoma (2 cases); for chronic nonspecific inflammation (2 cases); for bronchial stenosis (2 cases); and for actinomycosis and multiple cysts (1 case each).

There were 3 deaths in these 16 pneumonectomies, 2 on the operating table, as the result of complete blockage of the contralateral bronchial tree with tenacious mucoid material; both occurred immediately after removal of the

involved lung, though in both, there had been repeated aspirations of the tracheobronchial tree during operation.

Three of the patients who had undergone pneumonectomy later required thoracoplasty. The others did well.

4. Tumors or cysts were removed from the mediastinum in 19 instances. Subtotal removal of the growths in two other instances ended fatally. One patient had a malignant teratoma, and death was caused by cerebral anoxia during operation. The other patient, who had a tumor of the thymus associated with myesthenia gravis, died of his disease.

In a number of other instances, exploratory thoracotomy was carried out, but the malignant lymphomas and other tumors thus revealed were considered inoperable.

5. Although the Kennedy General Hospital thoracic surgery center was not intended for the treatment of pulmonary tuberculosis, it treated five patients who were receiving therapeutic pneumothorax and all of whom were referred for division of adhesions. This proved possible in only one instance. The other four patients underwent thoracoplasty, with excellent results in all.

6. Ten patients with chronic spontaneous pneumothorax of nontuberculous origin, which had lasted from 2 to 18 months, were treated surgically. In three instances, the pneumothorax was the result of rupture of large pulmonary cysts. In two instances, only a small amount of pulmonary tissue had to be removed along with the cyst. In the third case, subtotal resection of the lobe that contained the cyst was necessary. In one case, the only surgery necessary was division of a band of adhesions that was maintaining the patency of a bronchopleural fistula. In the six remaining cases, the procedure was limited to removal from the pulmonary surface of the constricting thickened pleura that had apparently followed the complete collapse of the lung after rupture of a peripheral bleb. In all instances, there was prompt reexpansion of the collapsed lung.

In an additional case, a patient with three recurrences of chronic spontaneous pneumothorax over a 2-year period refused surgery, and complete expansion of the lung finally occurred without it.

7. The 137 patients treated at the chest center with various lesions of the esophagus are described in detail elsewhere (vol. II, ch. X).

Endoscopy.—As in all other chest centers, the performance of peroral endoscopy was a responsibility of the thoracic surgeons. Practically all members of the staff were qualified, and during the period the center was in operation, they performed 966 bronchoscopies, 525 bronchographies, and 50 esophagoscopies.

Results.—The excellent results obtained in the lobectomies and other operations performed at the Kennedy General Hospital chest center can be attributed to a combination of factors: The patients were young and in generally good condition. Their wounds had been well handled overseas. Their diseases were usually of relatively short duration. Anesthesia was excellent. Surgery was competent. Adjunct therapy included the liberal use

of whole blood. Finally, the postoperative nursing care was of the highest quality.

Walter Reed General Hospital

Facilities.—In May 1945, facilities for the thoracic surgery center at Walter Reed General Hospital were of four types:[3]

1. Two open wards, each containing accommodations for from 30 to 45 enlisted men. Additional facilities were obtained as necessary by borrowing beds from other specialty services.
2. A smaller ward containing accommodations for from 15 to 25 officers.
3. Wards for ambulatory enlisted men and officer personnel. These wards were temporary structures on the hospital grounds, capable of accommodating from 50 to 100 patients. These patients reported daily to the central nursing station in the center for dressings or, if necessary, changes of therapy.
4. Convalescent wards at Forest Glen Annex, Forest Glen, Md., a converted girls' school about 3 miles from Walter Reed proper.

Population.—The population of the Walter Reed General Hospital chest center consisted of the following groups of patients:

1. Occasional single admissions, particularly transfers from other hospitals in the Zone of Interior.
2. Chest casualties from overseas, who were usually received in groups after they had been returned to the Zone of Interior by plane or hospital ship and had been designated for a chest center after triage at the port of embarkation.
3. Patients from overseas with intrathoracic neoplasms or other chest conditions, which might or might not have existed before induction.
4. Patients with neoplasms or other chest conditions found after induction or on separation from service. Roentgenologic examination was a routine part of the preinduction examination, but neoplasms were occasionally overlooked or, as inquiries of the patients suggested, roentgenograms were occasionally not made. The surprising number of asymptomatic lesions detected on the final survey clearly indicated the advantages of this method of case finding. In all such cases, the patients were referred to chest centers.
5. Patients referred from other chest centers as they were closed. When Walter Reed and Fitzsimons General Hospital chest centers were the only centers to be kept open, patients remaining in the other centers were referred to them. As a result, the Walter Reed chest center did not show the steady decline in population which occurred immediately after the war in other centers for specialized care. Unfortunately, as the patient census rose, the staff of the center suffered a gradual attrition as key personnel in it returned to civilian life.

[3] No final report of the Walter Reed General Hospital thoracic surgery center was prepared, but at my request, Dr. Donald B. Effler searched his files and his memory and prepared the material summarized herewith. It is of particular value because of the light it sheds upon the opportunities for training in this specialty which were available to a medical officer whose sole concern was the professional care of his patients and his own professional education.—J. B. C., Jr.

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The population of the chest center provided three chief clinical problems: battle wounds, suppurative disease, and tumors. From 60 to 70 percent of the casualties with war wounds arriving from overseas needed no active treatment, simply routine clinical and roentgenologic examinations before discharge. As the war drew to an end, the surgery of trauma decreased, and civilian-type diseases occupied most of the time of the staff; these conditions were not related to military service but were, of course, considered in line of duty. The distribution of the work in chest centers was in contrast to that in neurosurgical and orthopedic surgery centers, in which practically all therapy during their entire period of operation was for combat-incurred injuries.

Organization.—The thoracic surgery service at Walter Reed General Hospital did not depend on surgical officers of the day from other services. Instead, it was covered 7 days a week, 24 hours a day, with its own staff. This was probably one of the reasons that disciplinary problems were almost unheard of among the patients on this service.

Departmental conferences, usually informal, were held at least 5 days a week. Here new patients were surveyed, problem cases discussed, and surgical schedules for the following week drawn up. The patients were assigned by the chief of the center (in May 1945, Colonel Blades) to the medical officers best equipped to handle them. Patients were proposed for operation by the various officers on the staff, but all decisions concerning major surgery were ultimately passed on by the chief of service. The schedule for elective surgery was so heavy that it ordinarily ran from 2 to 5 weeks behind.

A tumor board met weekly, at which all patients suspected of harboring neoplasms were presented and discussed. This policy resulted in the best possible care for these patients and also provided a most instructive teaching technique.

There was close liaison with all other departments in the hospital, particularly the departments of anesthesia and radiology. Both furnished excellent supporting services.

Processing and disposition of patients.—Many patients with chest injuries received at the Walter Reed General Hospital chest center required no treatment. They were admitted simply for processing and ultimate disposition; that is, either return to duty or separation from service.

Each of these patients was interviewed and examined by a member of the staff of the center, and a complete record was compiled for him. Although this plan sometimes resulted in a duplication of paperwork, it seemed justified: In many instances, the original records had either been lost or were entirely inadequate. Most professional personnel who had treated these patients initially were not thoracic surgeons but harassed medical officers, who were frequently swamped by the tremendous volume of casualties.

This policy was executed smoothly and in a surprisingly short time; one reason for this was the competent service of the Women's Army Corps and civilians who supplied secretarial aid. Each patient thus had a satisfactory,

complete record that assisted in his disposition and also protected both him and the hospital from the military standpoint.

Patients who had recovered from major surgery were transferred to the convalescent section of the hospital if supportive therapy such as physical medicine or remedial exercises was needed. Otherwise, they were given 30-day sick leaves. When they had returned from leave, they were reexamined, and, if no further professional care was indicated, their disposition was undertaken. If they were to be returned to duty, they were transferred to a nearby reassignment center.

Recommendations for separation from service were made by the staff of the thoracic surgical section, to the surgical staff, and thence to a disposition board, which recommended either retirement or disability separation. As indicated elsewhere (vol. II, ch. IX), a great many patients in World War II were classified as partly or totally disabled because they had undergone lobectomy, excision of nonmalignant tumors, or other chest surgery, or because they harbored retained foreign bodies. In the light of present knowledge, they would not be so classified. During World War II, however, and immediately afterward, the time factor was too short, and knowledge of the specialty was too incomplete, to determine the ultimate fate of the casualty who had undergone major chest surgery. As a result, doubts were resolved in his favor, which worked an economic hardship on the Government. There is no doubt that many a casualty who was honorably discharged on full disability in World War II would now be considered to have undergone a routine elective operation that would not require him to be away from his duties for more than from 6 to 10 weeks.

Clinical policies.—Surgical policies at the Walter Reed General Hospital chest center were essentially the same as at other centers. Two points might be commented on:

1. The recovery room that is now standard in most hospitals was a novelty in World War II, and it is believed that the one set up on the thoracic surgery service at this hospital was the first of its kind in Army hospitals, at least in this specialty. It was provided with constant wall suction, oxygen, and other mechanical devices and equipment for routine care and to meet any emergency.

2. Penicillin was used aggressively by the depot technique devised by Romansky.

3. Early ambulation was an important part of the postoperative program, though it was still not generally accepted in either military or civilian hospitals. What this plan really amounted to was the application of outpatient principles to an inpatient service. As soon as a patient was classified as ambulatory, he reported as necessary to the central dressing room, where dressings were changed, sutures removed, and empyema cavities treated. This was excellent treatment for the patient, who recovered his strength much more rapidly when he was permitted to get out of bed promptly. It was also a laborsaving plan,

for 20 patients could be processed in this manner by the short-handed professional staff in the time it would have taken to care for 5 bed patients. This plan also facilitated the training of new corpsmen.

Training.—The quality of the training received at the Walter Reed General Hospital thoracic surgery center is apparent in the comment on it in a letter received from Dr. Donald B. Effler, on 1 September 1960. He wrote, in part:

When I reported to Walter Reed for duty, after a year's internship and 2½ years of oversea service, I made it quite clear to Colonel Blades that I had absolutely no knowledge of thoracic surgery. This seemed to delight him, on the ground that he would have one man on the service who would offer no suggestions for changing anything.

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I received an immediate impression of high professional and patient morale not only in thoracic surgery but throughout the whole hospital. I doubt if any civilian or military institution ever had staff or faculty of a higher overall quality. Administrative problems were always subordinated to patient care. I believe all of the men in the thoracic surgery service are now heads of thoracic surgery departments in important medical schools.

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The intensive training program offered me was accompanied by a steady increase in my professional responsibilities. This was almost necessary. As the war drew to a close, with the capitulation first of the Germans and then of the Japanese, a mass evacuation of civilian physicians from the Army began. Those who had the most experience and were oldest in service were naturally the most anxious to leave. Along with the attrition of the staff went the increase in the population of the center as other centers closed. At the same time, there was an influx of civilian and military visitors, most of whom were greatly interested in the functioning of the thoracic surgery service. Many ranking medical officers returning from administrative posts overseas also returned to Walter Reed for refresher courses.

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When Colonel Blades was separated from service, he was immediately appointed by The Surgeon General as civilian consultant in thoracic surgery at Walter Reed. He visited the hospital regularly, and he was always available for telephone consultation, or he would visit the hospital aside from his regular visits if I needed his opinion on any patient. Maj. Vincent M. Iovine, who left the hospital to become chief of surgery at Mt. Alto Veterans Hospital in Washington, also retained his interest in the department and was very helpful to me.

At this time I was still a captain in the U.S. Army Medical Corps, perhaps the only captain in the history of Walter Reed who was chief of thoracic surgery (and also in charge of ward 8, later converted into the Presidential suite). Considerable humor was added to the situation by the fact that my two senior residents were full colonels and my assistant resident a lieutenant colonel (this was Lt. Col. Jack Paul, who 2 years later became chief of the thoracic surgery service). I doubt if in the hospital annals anybody with the rank of captain carried as much professional responsibility or had as much rank under him as I did in the last months of 1946. I was still a captain when I was separated from service January 1, 1947, but I was promoted to major the following day. This was a source of great amusement to many of my friends, as indeed it was to me. But the training at Walter Reed was so superb and the opportunities so tremendous that in themselves they furnished the only reward I wanted.

A letter such as this needs no editorial or other comment.

REGISTRY OF FOREIGN BODIES

A proposal during the war that a registry of retained foreign bodies be set up, along the lines of the Peripheral Nerve Registry, did not materialize, chiefly because the statisticians consulted did not think it feasible to obtain sufficient controls. After the war, another attempt was made to initiate such a study through the Veterans' Administration, but again the plan did not prove workable. It was easy enough to find patients from whom foreign bodies had been removed but more difficult to persuade patients with retained foreign bodies to report to the Veterans' Administration for observation and roentgenologic studies; many of them frankly stated that they feared the loss of disability pensions. It is unfortunate that the proposed registry could not be established because only such a study will eventually settle the question of whether or not retained foreign bodies should be removed, and, if they should be, on what indications.

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Part III

GENERAL MANAGEMENT OF WOUNDS OF THE CHEST

CHAPTER VI

Evolution of Clinical Policies in the Mediterranean (Formerly North African) Theater of Operations

Thomas H. Burford, M.D.

GENERAL CONSIDERATIONS

Until the Korean War, which broke out 5 years after World War II ended, all the wars in which the United States has been engaged were relatively widely spaced. Surgeons therefore had to approach their medicomilitary duties without practical experience of combat-incurred trauma. This meant that, in every new war, the lessons of the previous war had to be relearned.

In World War II, thoracic surgeons had to overcome three special difficulties:

1. They had to learn, as do all civilian surgeons who enter the Army, that the problems of medical care in wartime are not entirely clinical. The clinical care of battle casualties is closely related to other considerations, including supply; personnel; evacuation and transportation, which in turn are related to terrain, time factors, the weather, and other military necessities; the facilities available for medical care; and, most of all, the tactical situation, in which the enemy often plays a determining role.

2. Thoracic surgeons were practicing a relatively new specialty in World War II. Their number was limited, and the thoracic surgery of civilian life, even of the traumatic variety, had only a limited application to military thoracic surgery.

3. The experience in World War I—this aspect of it, as least, was generally known—had been so overwhelmingly concerned with empyema of nontraumatic (postinfluenzal, postpneumonic) origin that it was only natural for the chest surgeons of World War II to enter upon their duties believing that their major problem would be the prevention of intrathoracic infection. As a matter of fact, this type of infection was to prove a relatively minor problem in this war.

The management of thoracic casualties as it finally evolved in MTOUSA (Mediterranean Theater of Operations, U.S. Army), and was later carried out in the European Theater of Operations, U.S. Army, was based on sound physiologic principles and good surgical practices. The care of the casualty

began with the all-important emergency measures instituted—often heroically—on the battlefield by the company aidman, and it extended uninterruptedly through the entire chain of evacuation. Consistency of concepts underlay continuity of treatment. There were no pathophysiologic echelons. The program instituted countenanced no compromise short of ideal surgical results. The assiduous application of sound surgical and physiologic concepts made apologies for the exigencies of war entirely unnecessary. Experience in the Mediterranean theater, and later in the European theater, showed that ideal results were entirely feasible and could be achieved.

Such a program did not exist at the beginning of World War II. It was developed by a process of evolution. Furthermore, more than mere formulation of such a program was necessary. The hiatus that originally existed between the concepts at consultant and other specialized surgical levels and the practices on other, lower levels had to be bridged by didactic teaching, demonstrations, discussions, and directives. In all hospitals, as might have been expected, the single factor that contributed most to the success achieved in the management of chest injuries and the promptness with which it was attained was insistence by the chief of section upon rigid and undeviating adherence to the surgical principles and practices laid down by the chief consultant in surgery in the theater.

The policies by which thoracic injuries were managed were not, of course, instituted in their final efficient form in the early operations in World War II. Circumstances of military care varied from theater to theater and changed as the war progressed. As a result, the outstandingly good results achieved late in the war were not achieved early in the war. In the last months of fighting, however, perhaps from 70 to 75 percent of the casualties received in Zone of Interior general hospitals and thoracic surgery centers from the Mediterranean and European theaters were practically well from the standpoint of their thoracic wounds. (Casualties from the Pacific theaters always presented different problems.) Many of them were evacuated because of associated wounds. When the chest injury was the principal wound, in many instances only the original severity of the wound, the need for reconditioning, and the uncertainty regarding the man's ability to perform full military duty in an oversea theater indicated his return to the United States.

STAGING OF SURGICAL CARE

At the deliberate risk of repeating what has already appeared in published volumes of the history of the U.S. Army Medical Department in World War II and will appear, in greater detail, in volumes in the administrative series now in preparation, certain facts concerning the general care of the wounded in a combat zone must be described before the management of thoracic injuries is discussed. The repetition is necessary because chest injuries were managed according to these basic principles as well as according to principles applicable only to these special injuries.

The entire system of medicomilitary care in World War II was based on the following premises:

1. Medical care must be accomplished in echelons.
2. The mission of each echelon is both specified and limited.
3. Medical installations in combat and communications zones, as well as in the Zone of Interior, are designed, equipped, staffed, and designated for specific missions.
4. Medical officers must not only perform the duties specified for their particular echelons but must also limit themselves to the duties specified for them at those levels.

The surgical management of battle casualties was rendered in phases which, in general, conformed with the personnel and facilities provided by the medical installations in the several echelons of medical service. These phases included:

1. Emergency measures on the battlefield and in the battalion aid stations and other installations forward of the clearing station (division area).
2. Initial wound surgery, which was rendered, according to the condition of the casualty and other circumstances, in the field hospital (division area) or the evacuation hospital (army area).
3. Reparative surgery, which was rendered in general or station hospitals or in centers for specialized care (communications zone).
4. Reconstructive surgery, which was rendered in the Zone of Interior.
5. Reconditioning and rehabilitation, which were carried out overseas or in the Zone of Interior, depending upon where the casualty had received his final surgical care and whether he could be returned to duty from a hospital overseas or had to be evacuated to the United States.

The entire process of evacuation of the wounded man had three objectives:

1. To get him out of the way of battle, in which he was no longer useful and might never be useful again.
2. To restore him to combat efficiency, if that were possible.
3. To save life, relieve suffering, and prevent deformity.

While these objectives are listed in the order of their military importance, there was, of course, no conflict between the humane considerations of the third objective and the military necessities of the first two objectives.

The process of evacuation and the determination of the forward echelon in which the patient would receive initial care depended upon two considerations:

1. His transportability (p. 204), which was determined by the character of his injury and his physiologic reaction to it.
2. The measures required to care for his wound.

The continued backward movement of a military casualty from area to area was in sharp contrast to the management of civilian victims of trauma, who are practically always managed throughout their clinical course in the same hospital to which they are first admitted. It was also responsible for

other differences between the civilian and the military surgery of trauma:

1. In military surgery, the timelag between wounding and definitive care was many times longer than in civilian practice because of the necessity for evacuation of the casualty from the battlefield through the battalion aid station and the collecting station to the clearing station, at which level hospital facilities were first available.

2. Perhaps the most important difference between civilian and military practice concerned personnel. In civilian surgery, a single surgeon usually makes all the important decisions for a single casualty. In military surgery, these decisions had to be made by a number of surgeons. From the time a wounded man was tagged on the battlefield and removed to a battalion aid station, until the completion of his cycle of treatment, evacuation, and disposition, he was cared for not only in a series of medical installations but also by a series of medical officers whose judgment and performance were interwoven in the threads of his care. Every medical officer who treated a wounded man was called upon to evaluate the patient's status. He also had to estimate his own surgical capabilities and limitations and the facilities at hand to perform the necessary surgery. In the division area, and frequently in the army area as well, all surgery was attended with some degree of urgency, and the decisions had to be made in the light of circumstances peculiar to a field army in combat.

Two planned policies compensated for these obvious disadvantages in the care of casualties:

1. The precise definition and timing of surgery in the various echelons of medical care. Every procedure was timed and graded in relation to the total picture, including the tactical situation, the particular point in the chain of evacuation, and the wounded man's own status. Hospitals, as already noted, were designated and equipped for surgery of varying degrees of urgency and magnitude, and with due consideration of the necessary duration and other requirements of postoperative care. They were strategically placed in reference to these considerations, and professional personnel of the appropriate competence were assigned in accordance with the function of the installations and the type of surgery to be performed in them.

2. Standardization of management, or, as many medical officers fresh from civilian life preferred to term it, "regimentation." This policy was essential because of the transfer of the care of the wounded man from medical officer to medical officer as he was evacuated farther to the rear. For reasons of simplification, expedition, and safety, individual variations of any consequence could not be permitted. The surgeon who cared for a casualty in the rear area had to know exactly what had been done by the surgeon in the forward area, so that he could relate his own therapy to what had already been done and what remained to be done.

With the passage of time since the end of World War II, some of the general principles and practices just summarized may have been forgotten. It is particularly important that these principles and practices be clearly understood as the background of the discussion of thoracic wounds in World War II.

They greatly affected the management of these wounds. There were no other combat-incurred wounds in which alterations of physiology could be so rapidly fatal, and no others in which physiologic disturbances could be corrected so simply and so rapidly by the proper measures. When these disturbances had been corrected, the majority of chest casualties became safely transportable. The corollary was that a casualty who, in his original status, would have required definitive treatment far forward could be treated with safety and convenience farther to the rear, thus relieving the strain on the medical installations that were always most heavily taxed.

The continuous system of triage (p. 202) in the chain of evacuation made it possible for a casualty to receive adequate treatment, as he required it, at each hospital along the evacuation route. The hospitals were in no sense stopping-off places. Each was established for the specific purpose of treating the casualty at the optimum time that his wound and his reaction to it required some special measure, including surgical measures.

OFFICIAL POLICIES IN CHEST INJURIES

When the United States entered World War II, the only official policies for the management of chest wounds were laid down in military manuals then in preparation and in a manual, also in preparation, by the Subcommittee on Thoracic Surgery of the Committee on Surgery, Division of Medical Sciences, National Research Council (*1*).

Military Manuals

War Department Field Manual 21–11, First Aid for Soldiers, published on 7 April 1943, was intended to teach the soldier what he could do for himself or for a fellow soldier if injury or sickness occurred when no medical officer or medical corpsman was nearby. The material on wounds of the chest was, in substance, as follows:

If the chest wound is one in which air is sucking in and blowing out, the life of the injured man may depend upon the speed with which a dressing, large enough to cover the wound and stop the flow of air through it, is applied. If the dressing applied does not completely stop the back-and-forth movement of air, additional dressings should be applied. A large piece of any available material (raincoat, overcoat, blouse, or shirt) applied tightly over the dressing may be useful in making it airtight.

The casualty with a wound of the chest is more comfortable and can breathe more easily if he lies on the injured side.

War Department Technical Manual 8–210, Guides to Therapy for Medical Officers, published on 20 March 1942, contains, in reduced form, essentially the same material appearing in the thoracic surgery section of the National Research Council military surgery manual entitled "Neurosurgery and Thoracic Surgery" (*1*).

National Research Council Manual

Plan of manual.—When a manual on chest surgery was first under discussion, it was the desire of Dr. Evarts A. Graham, who served as Chairman of the Subcommittee on Thoracic Surgery, that it should not exceed 50 pages. When it was finally published, in 1943, it had exceeded this length by 29 pages. It is unfortunate that this manual did not fulfill its potential usefulness. It did not appear until policies were being evolved as combat necessities developed. It had no general circulation among medical officers, and no official instructions for its use were issued. The thoracic surgeons in the Mediterranean theater, who had most to do with the evolution of policies for chest injuries, were not even aware of its existence as such, though the substance of the material in it, as just stated, was available to them after March 1942 in War Department Technical Manual 8–210.

It was stated in the preface to the National Research Council manual that the high mortality rate of chest wounds—33 percent on the field, 25–30 percent in dressing stations, and 20–25 percent in ambulances—made it clear that if any reduction were to be achieved in the number of deaths from these injuries, the improvement must take place in the combat zone. The desired improvement would not be brought about by the indiscriminate application of heroic surgery in advanced surgical stations. It could be achieved only by accurate appraisal of the individual patient, prompt emergency measures, and definitive attention to special aspects of thoracic wounds.

Among the subjects specifically excluded from the manual was the complete exposition of the physiopathology of the cardiorespiratory mechanism, on the ground that this information could be obtained from standard texts. This, of course, is true, but in view of the complete change of emphasis in the management of wounds of the chest between World Wars I and II and the emphasis in World War II upon physiologic derangements, it is unfortunate that space was not utilized to emphasize this important phase of these wounds.

The book is divided into four parts. The first concerns the general principles of management of chest injuries. The second is a synopsis in outline form of the treatment and disposition of these injuries. The third deals with their complications and sequelae. The fourth deals with operative surgery.

The substance of the recommendations was as follows:

First aid measures.—First aid measures outlined in this manual include arrest of hemorrhage from the thoracic wall, physical correction of physiologic disturbances, and measures to prevent infection. In the brief discussion of these measures, both sucking wounds and their closure are specifically mentioned, as in stove-in chest. It is recommended that hemorrhage from a lacerated lung should be treated by aspiration and simultaneous artificial pneumothorax, although the practice of air replacement had long since been discontinued when this manual appeared. Aspiration is recommended for pericardial tamponade.

Definitive treatment.—Subsequent surgery is to be carried out under intratracheal anesthesia, to provide differential pressure. Debridement, by a somewhat elastic definition of the term, might include removal of high explosive fragments from the lung, though in

some instances, their delayed removal is wiser; resection of devitalized or bleeding pulmonary tissue, a policy that was seldom employed in chest wounds in World War II; hemostatic suture; airtight closure of divided bronchi; removal of foreign bodies and devitalized tissue from the pleura and thoracic wall; reexpansion of normal pulmonary tissue; and airtight closure of the thoracic wall.

Prompt intervention is urgently necessary in the presence of progressive bleeding, early open pneumothorax, pressure pneumothorax, and cardiac tamponade. The early control of infection is desirable but much less imperative and is never an excuse for an inadequately equipped medical officer to undertake thoracotomy. If empyema occurs, in spite of efforts to prevent it, proper drainage is to be instituted, to prevent a chronic phase.

The question of whether or not intervention is carried out in a forward installation often rests upon the ease or difficulty with which evacuation can be accomplished. Air transportation is desirable but, unless oxygen is available en route, it must not be employed in anoxemia or in wounds associated with large closed pneumothoraces.

Special types of injuries.—Injuries and conditions covered in the second chapter of this manual include tangential or nonpenetrating wounds, in which the pleural cavity has not been entered and which may or may not be associated with hemoptysis; similar wounds associated with simple rib fractures; compression injuries with traumatic asphyxia; extensive mobilization of the chest wall by rib fractures; massive atelectasis; penetrating injuries, with and without serious hemorrhage and shock and sometimes associated with subcutaneous emphysema; perforating injuries; pleuroabdominal wounds; rupture of the diaphragm; and blast injuries. Treatment under each of these headings is divided into first aid measures and definitive treatment. As will be evident later, both the nomenclature and the emphasis in a number of these injuries differ from the nomenclature and the emphasis in the injuries encountered in World War II.

Complications and sequelae.—Complications and sequelae dealt with in the third chapter of the manual include pneumothorax, emphysema, hemothorax, empyema, retained foreign bodies, infections of the chest wall, lung abscess, massive hemorrhage into the subfascial spaces of the thoracic wall, and complications of wounds of the heart.

It is striking that hemothorax, the management of which proved so highly important in World War II, receives little attention in this volume. In chapter I, it is pointed out that hemorrhage into the pleural cavity may be fatal "without serious disturbance of respiration being caused by encroachment on pulmonary volume"; that the mechanical effects of hemothorax are delayed because they are produced by a traumatic effusion superimposed upon an initial collection of blood; and that the tendency to spontaneous hemostasis is the result of a low head of pressure in the pulmonary circulation plus the collapse of the lung from attendant hemothorax or pneumothorax.

In the chapter on complications and sequelae, hemothorax is covered in a page, practically all of which is devoted to differential diagnosis (massive pulmonary collapse, rupture of the diaphragm with displacement of the abdominal viscera into the thoracic cavity, pleural effusion of infectious origin, and consolidation of a contused or pneumonic lung). Treatment is limited to cross-references to hemorrhage and shock; penetrating injuries with shock and hemorrhage from pulmonary lacerations; and infected hemothorax, which receives only half a page of the 3½ pages devoted to empyema. Neither clotted hemothorax (vol. II, ch. I) nor decortication (p. 27) is mentioned.

Technique.—The final chapter of this manual describes the techniques for autotransfusion, bronchoscopy and tracheal intubation, thoracentesis, pericardicentesis, artificial pneumothorax, intercostal catheter drainage, elevation of stove-in chest, pericostal suture for hemorrhage from the intercostal artery, ligation of the internal mammary artery, rib-resection drainage in empyema, thoracotomy for penetrating wounds, exteriorization of the lung, drainage of lung abscess, removal of foreign bodies from the lung, cardiorrhaphy, pericardiostomy, management of mediastinal emphysema and wounds of the trachea, tracheotomy, mediastinotomy, repair of thoracoabdominal injuries, repair of traumatic diaphragmatic hernia, and the management of cardiac arrest.

There are some techniques in this list that were abandoned in World War II because better methods were found or because there was no need for them. Exteriorization of the lung, for instance, was never practiced. Pericostal sutures for any purpose were found harmful. Lung abscess was very infrequent. It will be observed that, again, there is no mention of decortication in this list of procedures.

Anesthesia.—Differential pressure anesthesia is recommended for all major operations in which the pleura is widely opened. It is preferably carried out by tracheal intubation. Agents combined with a high percentage of oxygen are preferred to those whose use is associated with anoxia. Regional block or infiltration anesthesia may be used for operation on the thoracic wall, and local anethesia may be employed to supplement general anesthesia.

Adjunct therapy.—The infusion of blood substitutes rather than whole blood is recommended in any injury that reduces pulmonary volume and causes shock accompanied by hemoconcentration. By the time this manual appeared, a great deal more had been learned about shock, and it had long since been found that plasma was not an acceptable substitute for whole blood in seriously wounded men. The advice to delay blood replacement as long as possible in the presence of continuing intrapulmonary hemorrhage was sound if steps were taken to control the hemorrhage at once, and the warning against overhydration of casualties with chest injuries was also sound.

Oxygen is recommended for "asphyxia." Morphine is to be used cautiously, because the advantage of relief of pain may be counterbalanced by abolition of the cough reflex or the production of respiratory depression. Atropine may be used to lessen vagal reflexes and diminish the secretion of mucus, though it has the disadvantage of increasing the viscosity of bronchial secretions and making it more difficult to clear the bronchial tree by coughing. Barbiturates are usually contraindicated. Codeine or cough mixtures are not used when it is necessary to evacuate purulent secretions by coughing. Respiratory stimulants are seldom required or effective. Carbon dioxide is used with caution. If tobacco does not incite coughing, it may be used in moderation during recovery. Early ambulation and deep breathing are stressed.

A crystal sulfonamide is used in the pleural cavity and in the wound of the thoracic wall, and systemic chemotherapy is also employed. The manual warns that the sulfonamides are not a substitute for proper surgery.

Some of these measures were used in the management of chest injuries in World War II, but many of them were replaced by far more energetic measures, including catheter suction, and bronchoscopy as indicated, to clear the tracheobronchial tree. Even before penicillin had become available in World War II, local sulfonamide therapy had been generally discontinued.

Comment.—Excellent as are many of the recommendations in this manual, the book suffers from the same fault that surgeons in other specialties have attributed to other manuals in the series: It is somewhat removed from the realities of combat, and the World War II experience did not bear out some of the statements in it, as the following example indicates: "* * * Necessity for prompt evacuation need not be understood to contraindicate treatment at advanced stations, for men wounded in the manner considered here often stand transportation better in the first twenty-four hours after operation than they do a few days later."

In the World War II experience, casualties with chest injuries stood transportation well after the correction of their cardiorespiratory disturbances and were also less susceptible to infection. Provision was made in both field and evacuation hospitals for holding patients after operation; the disasters of

the prompt evacuation practiced in the first months of the war had proved conclusively that casualties with serious chest injuries do not tolerate transportation well at this time.

The warning against radical forward surgery was in agreement with the World War II experience with that variety of management:

> Choice of station at which definitive surgical treatment of thoracic injuries with severe laceration of the lung is instituted is governed by military exigencies and the equipment and assistance available. Decision between operation and conservative treatment must be shaped by the facilities at hand and the competence of the surgical team. Remember that infection of the pleural cavity may be dealt with later, while open operation under unfavorable circumstances may lead to disaster.

This means, as is pointed out in more than one place in this manual and as was proved by the early experience in World War II, that early open thoracotomy by an inexperienced surgical team is extremely hazardous.

EARLY EXPERIENCE IN THE MEDITERRANEAN THEATER

North Africa

There was considerable confusion in the management of all combat injuries in the early days of the fighting in North Africa, for several reasons:

1. Official policies, as just pointed out, did not yet exist. The manuals in which they were described appeared late and were incorrect, in a number of areas, in both emphasis and techniques.

2. The lessons of World War I, explicitly set forth in the official history of the Medical Department, were generally unknown. No real attempt had been made to utilize this valuable material. The emphasis in thoracic injuries in World War I was, as already noted, overwhelmingly on the septic rather than the traumatic side, but there was still a great deal in the story of chest trauma that would have been of great practical value.

3. Almost no U.S. Army medical officers in the North African theater were familiar with the lessons the British had learned in the 3 years in which they had been at war; during this period, the British had had an extensive experience in this theater. Eventually, untried American thoracic surgeons learned a great deal from British surgeons, but early attempts to capitalize on their experience were only partly successful. When the 77th Evacuation Hospital was in England in 1942, before it was sent to North Africa, the time which its thoracic surgical team finally spent in British chest centers was only a fraction of what had been originally planned (*2*).

When this and other evacuation hospitals and auxiliary surgical group teams arrived in North Africa, in November 1942, and took over the hospitals in Oran, they found that many patients with chest wounds had received little or no care. Wounds had not been debrided. Sucking wounds had not been closed. Hemothoraces had not been aspirated. Even with the vigorous treatment immediately instituted, including chemotherapy, a great many hemo-

thoraces went on to empyema. Other handicaps existed at this time. Thoracic surgical instruments were in extremely short supply (p. 84), and there were no facilities for intratracheal anesthesia.

In March 1943, Maj. (later Col.) Howard E. Snyder, MC, head of the thoracic surgical team of the 77th Evacuation Hospital, was placed on temporary duty in II Corps headquarters, to evaluate the surgery performed in the early campaigns just concluded in North Africa and to make recommendations for the future care of casualties. His observations, which were reported to the Surgeon, II Corps, 3 April 1943 (*2*), were based on:

1. Visits to clearing and treatment stations, in some of which organic personnel had been supplemented by general surgical and shock teams from the 2d Auxiliary Surgical Group. Nontransportable casualties were treated at the clearing station of a medical battalion from 5 to 24 hours after wounding, after passing through two installations farther forward.
2. The 48th Surgical Hospital, 50 miles to the rear, to which transportable casualties were sent.

Major Snyder's report stated that, on the whole, triage had been well done, though some deaths that had occurred at the 48th Surgical Hospital might have been avoided if initial wound surgery had been performed at more forward installations. Other lives might have been saved if there had been less speedy evacuation of casualties operated on in forward installations; a number of these patients had been evacuated before they had even reacted from anesthesia. The selection of cases for surgery by teams of the 2d Auxiliary Surgical Group showed excellent judgment, and the surgery performed was generally commendable.

Major Snyder's recommendations were generally applicable to chest injuries:

1. Provision should be made for a more convenient method of blood transfusion, as well as for a source of blood other than clearing station personnel.
2. Provision should be made for oxygen therapy.
3. A shock team from an auxiliary surgical group should be assigned to every clearing station set up to act as a forward surgical hospital.
4. Caution should be exercised in the administration of morphine, to avoid overdosage, particularly in chest and intracranial injuries.
5. Better anesthetic equipment should be provided.
6. Facilities should be provided to hold casualties for a safe period of time in whatever installation they underwent major surgery.
7. More explicit directions should be issued concerning the emergency treatment of head and chest wounds and the disposition of these casualties.
8. Specialty teams for the treatment of these injuries should be assigned nearer the front than in evacuation hospitals, at least as these hospitals were located in North Africa; in some instances, they were as far as 145 miles behind the frontline.

Circular letters.—After the Tunisian campaign and before the invasion of Sicily, several circular letters were issued from the Office of the Surgeon, Headquarters, NATOUSA (North African Theater of Operations, U.S. Army), in which there were sections dealing with chest surgery.

Letter No. 13 (*3*), dated 15 May 1943, gave the following information concerning chest wounds in forward medical installations:

1. A sucking wound of the chest should be closed tightly enough "to prevent to-and-fro blasts of air with respiration but not so tight that air cannot escape from the chest if a pressure pneumothorax builds up from an accompanying wound of a bronchus." A pad of petrolatum-impregnated gauze should be folded to fit the wound; held in position by adhesive tape; and secured with one or two sutures, to prevent its loss into the pleural cavity.

2. Pressure pneumothorax should be promptly corrected by needle aspiration. If it re-forms, a small catheter should be inserted in the second interspace anteriorly.

3. Oxygen therapy may be as important as the administration of plasma. Aspiration of blood and air may make an otherwise nontransportable casualty transportable. Air replacement is "rarely" advisable. Internal bleeding is usually from the chest wall and requires revision of the wounds of entrance and exit. If the hemorrhage is from a large visceral or mediastinal vessel, thoracotomy is necessary.

4. Definitive surgery for thoracic wounds should be postponed until X-ray examination is possible. It is disastrous to assume that large retained foreign bodies will not promote infection.

Letter No. 16 (*4*), dated 9 June 1943, dealt with forward surgery with special reference to amphibious operations. In it, the instructions given in Circular Letter No. 13 concerning the closure of sucking wounds and the use of a catheter in pressure pneumothorax were repeated. Extensive surgical emphysema was to be managed by the correction of pressure pneumothorax.

Initial definitive surgery should be limited to debridement and closure of the wound of the chest wall, without complete suture of the superficial layers and skin. Local anesthesia was often satisfactory and eliminated the risk of asphyxia. Transfusions should be given slowly and only when essential.

Thoracic casualties (without specification) should be evacuated by air as "priority" patients, after preliminary aspiration of hemothorax without air replacement.

Letter No. 20 (*5*), dated 22 June 1943, contained the comments by hospitals in the communications zone on the treatment of battle casualties in forward areas during the Tunisian campaign. Generally speaking, these patients had been well treated and were received in good condition, but there were two adverse comments:

1. Some patients with chest wounds who had undergone exploration and removal of foreign bodies had been received with hemopneumothoraces and

collapse of the affected lung. Measures should have been taken to maintain an expanded lung.

2. Several patients were received with large, untreated hemopneumothoraces after being held in forward hospitals for as long as 10 days. Although X-ray facilities were available, they had not always been used. One patient with a large foreign body in the chest had a fulminating hemothoracic infection, but there was no mention of any examination of the chest, although the wound of entrance was obvious.

Sicily

In Sicily, as described elsewhere, there were two important advances in surgical management, both of which directly influenced the results obtained in all serious injuries. The first was the establishment of platoons of field hospitals directly adjacent to clearing stations, for surgery on nontransportable casualties (p. 91). The second was the effective use of auxiliary surgical group teams to augment the intrinsic personnel of field hospitals (p. 92).

Circular letter.—Circular Letter No. 3 (*6*), dated 7 August 1943 and issued in the field to all unit surgeons, dealt with the care of the wounded in Sicily. The section on wounds of the chest covered the following points:

1. The management of nontransportable casualties with wounds of the chest in field hospitals. Their number would be limited, the majority of such casualties being cared for in evacuation hospitals. Indications for transfer to a field hospital included dyspnea, sucking wounds, continuing hemorrhage, imminent shock, and thoracoabdominal wounds.

2. Indications for first aid measures in battalion aid stations, collecting stations, or clearing stations. These included:

a. Shock. The patient with a chest wound must not be placed in the Trendelenburg position. The amount of blood and plasma used should be only what was absolutely necessary, and it should be administered slowly.

b. Continuing hemorrhage from the chest wall, which should be controlled by ligature, hemostatic suture, or a mushroom pack.

c. Tension pneumothorax, which should be relieved as early as possible by the insertion of a large-bore needle in the second interspace anteriorly. For evacuation, a small catheter should be substituted for the needle, or a flutter valve should be used.

d. Open or sucking wounds, to be closed by the technique already described.

3. Initial wound surgery at a field hospital. This should be limited to debridement except in the occasional case of continued severe bleeding from the lungs, mediastinum, or heart; then thoracotomy should be done. Thoracoabdominal wounds required emergency surgery, which could sometimes be performed in toto through the thoracic approach.

4. Chemotherapy. Sulfanilamide should be dusted into the pleural cavity before closure, and an adequate sulfadiazine blood level should be maintained for from 7 to 10 days after admission.

5. Postoperative care, which was extremely important, whether or not thoracotomy had been done. Hemothoraces were to be aspirated daily if necessary. If drainage had been instituted, the catheter or tube was to be removed within 48 hours.

DEVELOPMENT OF CONCEPT OF CHEST INJURIES

When Col. Edward D. Churchill, MC, arrived in the North African theater in March 1943 and assumed his duties as Consultant in Surgery to the Surgeon, NATOUSA, then Brig. Gen. Frederick A. Blessé, it was the beginning of a fruitful association that was reflected in the care of all wounded, and not least in the care of thoracic casualties. Up to this time, in the absence of official directives, each chest surgeon had been proceeding according to his own training, experience, and personal preferences. There was no uniformity of opinion or practice concerning the indications for thoracotomy, its timing, the management of foreign bodies, or any other problem related to combat-incurred chest injuries. For all practical purposes, the chest surgeons at hospitals in the theater and those on the teams of auxiliary surgical groups were establishing their own policies.

Almost as soon as he arrived in the theater, Colonel Churchill began to emphasize the division of wound management into the initial phase, the reparative phase, and the reconstructive phase. The division proved increasingly sound because it made for more precise thinking and more logical management. The concept was particularly adaptable to the problems of thoracic trauma.

In spite of the obvious need for standardization in the management of chest injuries, Colonel Churchill issued no immediate directions for their management but set up, instead, what amounted to a number of clinical research problems in the hospitals in which thoracic surgeons were working, particularly the 9th, 11th, 38th, and 77th Evacuation Hospitals. The observations in these hospitals, and the policies developed from them, represented one of the truly significant advances in military surgery in World War II.

With careful observation of large numbers of chest wounds, it became clear that the reaction to them fell into two phases:

1. An immediate, urgent phase, characterized by disturbances of cardiorespiratory physiology that were often profound and that could be fatal if they were not corrected immediately, though not necessarily by surgery.

2. A delayed, nonurgent phase, characterized by infection. Infection was not an inevitable result of chest injuries, and, if it did develop, it was not an immediate complication.

The division of the bodily reaction to wounds of the chest into these two phases made it clear that their management also fell into two phases:

1. The immediate application of procedures that would result, expeditiously and uniformly, in the correction of acute cardiorespiratory abnormalities of traumatic origin. These measures, to be carried out in the most forward installations in which the proper facilities existed and competent personnel

were available, formed an essential part of resuscitation. As already indicated, they were not necessarily surgical. When they were effective, as they usually were, major surgery could safely be deferred until an evacuation hospital was reached.

2. The later performance, in the evacuation hospital, of debridement and such other surgery as might be indicated.

This routine frequently prevented infection. If infection developed in spite of these measures, it could be cared for in a fixed hospital in the communications zone.

It is important to note the shift of therapeutic emphasis in the management of chest wounds in World War II. In the First World War, the focus of attention was on the pleural space. In the Second World War, the focus of attention was on the cardiorespiratory apparatus. In the earlier war, the casualty was thought to be progressing satisfactorily as long as no pleural infection was evident. The same concept prevailed in the first few months of fighting in the Mediterranean theater in World War II. Then the emphasis shifted from the management of posttraumatic pleural infections to the preservation and restoration of pulmonary function, which frequently prevented the development of these infections or at least minimized their seriousness. What this amounted to was a complete reversal of the World War I concept that a casualty was in good condition if he did not develop empyema and the substitution for it of the concept that, unless pulmonary function was satisfactory, progress was not satisfactory.

One temptation had to be overcome: The sweep of technical advances in chest surgery between the World Wars was not a criterion of their applicability to the types of chest trauma encountered in wartime. The limitations of these procedures and their correct timing, as well as the echelon of medical care in which they were to be instituted, had to be defined by trial and error, in the hard school of medicomilitary experience.

FORMULATION OF POLICIES

As described elsewhere (p. 82), the first medical meeting of any Army on the European mainland during World War II was held in the King's Palace, Caserta, Italy, on 11 November 1943. The meeting was an outgrowth of the great interest in wound surgery on the part of the military surgeons who were doing the work and, particularly, on the part of the Surgeon, Fifth U.S. Army, and his administrative and consultant staffs. At this meeting, which was devoted entirely to chest wounds, there were laid down many of the principles of the rational approach to chest trauma which was later to become theater policy.

By this time, it had become clear to many of the thoracic surgeons in the Fifth U.S. Army that a conservative approach accomplished better results than a more radical approach; that is, the limited use of thoracotomy in forward hospitals. At this meeting, Capt. (later Maj.) Lyman A. Brewer III, MC,

presented an analysis of 90 penetrating wounds of the chest that he had personally handled by conservative measures.

The keystone of the conservative policy was the use of thoracotomy in forward hospitals only on strictly limited indications. Captain Brewer's personal experience to date, as well as the general experience in the chest center at the 53d Station Hospital at Bizerte, also showed that foreign bodies, whether metallic objects or bone fragments, even when they were of considerable size, did not, in themselves, constitute valid indications for either traumatic or formal thoracotomy in these hospitals. There was, of course, no objection to their removal if they were accessible through the wound used for debridement. In the course of the discussion, it was pointed out that the time required to stabilize these patients and transport them to hospitals in the base was so brief that the risk of infection supervening before the necessary surgery could be done was very slight indeed. The composite experience to date at the Bizerte thoracic surgery center showed that the case fatality rate in chest wounds was reduced by half when thoracotomy was performed only on limited indications and that the morbidity record was also greatly improved.

In March 1944, Colonel Churchill met at Marcianise, Italy, with Major Snyder, Consultant in Surgery, Office of the Surgeon, Fifth U.S. Army; Lt. Col. (later Col.) Frank B. Berry, MC, later Consultant in Surgery, Office of the Surgeon, Seventh U.S. Army; and a number of thoracic surgeons from the 2d Auxiliary Surgical Group, including Captain Brewer; Maj. Thomas H. Burford, MC; Maj. (later Lt. Col.) Lawrence M. Shefts, MC; Maj. (later Lt. Col.) Paul C. Samson, MC; and Maj. (later Lt. Col.) Reeve H. Betts, MC. Critical review of the experience with chest wounds in the theater showed the same pattern as at the November 1943 conference; that is, results were increasingly good when thoracotomy was performed in forward hospitals on strictly limited indications and were much less good when it was used on ill-defined indications. At the 24th General Hospital chest center, near Bizerte, for instance, Major Samson had found that 30 percent of all casualties with intrathoracic injuries had been submitted to major initial wound surgery at forward hospitals, and that half of this group had poor results. Maj. William M. Tuttle, MC, and his associates at the chest center at the 36th General Hospital, Naples, had had a similar experience: 39 percent of the patients admitted had already been subjected to major thoracotomy, and in 37.8 percent of this group the results were poor.

Basic Principles

The discussion at this meeting made it clear that considerable uncertainty still existed in the minds of many forward surgeons as to what constituted valid indications for thoracotomy as part of the initial wound surgery of chest injuries. It was agreed that the accrued experience of the theater was now sufficient to permit crystallization of the indications for major chest surgery in forward hospitals and for the establishment of a uniform, mandatory, theater-wide policy for the management of chest injuries.

As a result of the extended, detailed discussion at this meeting, it was decided that hereafter the policy for the management of these injuries should be based on the following principles:

1. The prime concern in the management of penetrating wounds of the chest is the timing of surgical intervention, and the proper spacing of surgical procedures, in forward and rear hospitals. In the forward area, the goal of therapy is the restoration of physiologic equilibrium. The complications of infection are usually delayed and, if they occur, they can, as a rule, be adequately managed at the base.

2. The physiologic disturbances that attend wounds of the chest are serious and urgent, but thoracotomy is not the way to control them. Appropriate measures include needle aspiration of air and blood from the chest, aspiration of blood and mucus from the tracheobronchial tree, control of pain by injection of the intercostal spaces with procaine hydrochloride, control of pressure pneumothorax by insertion of a catheter with a flutter valve, oxygen therapy, blood replacement, and debridement of sucking wounds (with hemostasis of bleeding vessels and approximation of deep structures of the chest wall to close the pleural opening).

3. Thoracotomy should be performed only on strict indications.

4. Closed drainage of the pleural space should be instituted after thoracotomy or after extensive surgery for a wound of the chest wall with involvement of the parietal pleura unless there are definite contraindications to its institution. The catheter should be removed as soon as the clinical course permits, which is usually within 48 hours.

5. A patient with an injured lung should be kept slightly dehydrated and depleted, since pulmonary edema can be invited by the too-liberal use of intravenous infusions or excessive transfusion.

6. The preferred thoracotomy incision or the extension of a missile track should be in the posterolateral area of the thoracic cage. Anterior incisions should be avoided, as they frequently break down after closure.

Indications and Contraindications for Thoracotomy

Indications for primary thoracotomy, either by extension of the wound or by separate incision at a site of election, were to be limited to:

1. Continuing intrapleural hemorrhage not controlled by hemostasis in the course of debridement of the chest wall, which was uncommon.

2. Anatomic or clinical evidence of penetration of the diaphragm, which was common.

3. Large intrapleural foreign bodies or other debris readily accessible by simple extension of the wound.

4. Wounds of large bronchi or of the intrathoracic portion of the trachea, which were uncommon.

5. Passage of a missile through, or its lodgment in, the mediastinum, with reason to suspect visceral damage, particularly injury to the esophagus.

The following conditions were not, in themselves, to be regarded as indications for thoracotomy either by extension of the wound or by a separate incision:

1. Foreign bodies, whether metallic objects or fragments of bone, whether they were in the lung or the pleural space.

2. Hemothorax. Evacuation of blood from the pleural cavity by suction at the time of debridement of the chest wall wound was not considered a thoracotomy.

3. Laceration or contusion of the lung in the absence of definite evidence of continuing hemorrhage.

Traumatic thoracotomy.—A considerable part of the meeting at Marcianise was taken up with a discussion of the advantages and disadvantages of traumatic thoracotomy; that is, thoracotomy performed through an extension of the traumatic wound or through the wound itself. As Colonel Churchill pointed out, it permitted such procedures as removal of accessible foreign bodies from the pleural space and of indriven bone fragments from the lung; control of bleeding from the chest wall remote from the wound of entrance; suture of presenting lung lacerations; evacuation of clotted blood; and visualization, appraisal, and sometimes suture, of diaphragmatic perforations.

It was dangerous, Colonel Churchill continued, to attempt to extend the utilization of this procedure beyond these definite limits. Its wise use depended upon a number of variables, including: The condition of the patient, the experience of the surgeon, the tactical situation with respect to evacuation and hospitalization, the anatomic location and the size of the wound, and the presence or absence of retained foreign bodies.

Traumatic thoracotomy thus occupied an intermediate position between simple debridement and formal thoracotomy. When the defect in the chest wall was large, little additional exposure was needed. When it was small, it could be enlarged by intercostal extension or rib resection. When it was properly employed, it could save life, prevent infection, and obviate the necessity for a second operation at the base.

Traumatic thoracotomy, however, had all the risks of any operation undertaken without a precise and predetermined goal and performed through an incision determined by the missile and not chosen by the surgeon. Intrapleural surgery in the presence of a traumatized and partially collapsed lung, instead of being beneficial, could delay pulmonary reexpansion and invite pleural complications or, if they already existed, make them more serious. Unwisely used, therefore, traumatic thoracotomy could unnecessarily delay the casualty's evacuation to the rear and even endanger his life.

Dissemination of Information

The policies just outlined were formally set forth in Circular Letter No. 46 (*7*), issued in NATOUSA on 29 August 1944. These policies were also incorporated in War Department Technical Bulletin (TB MED) 147 (*8*),

issued from the Office of The Surgeon General and dealing with the care of battle casualties. The same information was repeated in Circular Letter No. 8 (*9*), Office of the Surgeon, Headquarters, MTOUSA, in March 1945.

TRIAGE AND TRANSPORTABILITY

Triage

Some years after World War II ended, Colonel Churchill, Consultant in Surgery, Office of the Surgeon, Fifth U.S. Army, stated one of the eternal truths of military surgery (*10*): "* * * The biologic processes of wound infection and wound healing will not compromise with faulty medical administration * * * and are beyond the reach of command decision."

It was in the light of this truth that the evacuation of all wounded casualties was conducted. Evacuation was a selective process, determined by triage, which meant the sorting or selection of patients from the basic standpoint of whether or not they could withstand transportation farther to the rear. A number of other considerations also played a part. The degree of selection that was practical was profoundly influenced by the military situation. The number of available beds might be limited. There might be restrictions, imposed by the terrain or the tactical situation, on the movement or on the placement of hospitals. Transport might be in short supply. The patient might be able to withstand evacuation if it were not unduly extended but entirely unable to withstand it for any long period. Triage required a high degree of clinical ability, but it also had to be a completely objective process, in which humanitarian considerations could not be permitted to take precedence over medicomilitary necessities.

The closer to actual combat the casualty was seen, the less the element of selection determined his evacuation and the more weight was given to the single factor of his transportability. At the battalion aid station, the only selection possible was the separation of casualties rendered noneffective by their wounds from those who could be returned to their combat duties almost immediately. The same policies prevailed at the collecting station. At the clearing station, evacuation first became really selective, for both surgical and military reasons. It was militarily undesirable to perform major surgery in a forward area on any casualty who could be moved out of the combat zone without detriment to his condition. It was essential to move any casualty whose need for surgery was urgent to the field hospital adjacent to the clearing station.

Triage was always an individual matter. Only when a general retrograde movement was in progress did evacuation ever become a mass movement of all casualties away from the combat zone. Even then, certain nontransportable patients could be left to the care of an enemy known to respect the Geneva Convention. In all theaters, U.S. Army surgeons cared for many enemy wounded who had been left behind as their armies retreated.

Triage was also a continuous function. In the clearing station, the decision was made as to what casualties should go to the field hospital. In the field hospital, reevaluation after resuscitation often showed that the casualty who was originally nontransportable had become transportable and could safely be evacuated farther to the rear. On the other hand, no chances were taken. If there was any doubt at all as to his transportability, the casualty was kept in the field hospital and operated on there. Particular care was necessary in the group of patients just mentioned, those who seemed to become transportable after resuscitation. In some of them, recovery was more apparent than real, and fatalities occurred among them both during transportation and after they were received in evacuation hospitals.

Triage was of major interest to the individual casualty, but it was also important from the standpoint of other casualties. A platoon of a field hospital, even when supplemented by the personnel and equipment of attached auxiliary surgical group teams, still had a limited capacity. It was commendable to treat all casualties as far forward as possible, but it was impractical, and it was also harmful. Generally speaking, when the census of even an expanded platoon of a field hospital exceeded from 40 to 50 patients, these men could not be properly cared for. If a casualty whose condition permitted his evacuation were operated on in a field hospital, he occupied space, and utilized the time and attention of medical personnel, which might be desperately needed by another, more severely wounded casualty who could not withstand transportation.

Triage was thus a function of the greatest importance. Whenever possible, it was performed by the surgeons assigned to the particular hospital from an auxiliary surgical group. It could be properly carried out only by experienced medical officers.

The importance of triage was not immediately realized. Major Snyder, after an analysis of 80 deaths which had occurred in Fifth U.S. Army evacuation hospitals in January 1944 (*2*), concluded that some of them could have been prevented by more careful triage in clearing stations. If a larger number of casualties had been directed to field hospitals and cared for there, the results would certainly have been improved. Of 44 patients in deep shock or with first priority (nontransportable) wounds whose case histories Major Snyder studied, 36 were sent directly to evacuation hospitals from clearing stations. The other eight, although they were sent to field hospitals, were merely observed there and then sent to evacuation hospitals for initial wound surgery.

As a result of this survey, a medical circular was issued on 7 April 1944 (*11*), from the Office of the Surgeon, Headquarters, Fifth U.S. Army, dealing with the disposition of battle casualties in forward echelons. At the same time, an educational program was carried out in the clearing stations. The prompt improvement that occurred in the triage of casualties was reflected in improved results in all injuries and was maintained until the end of the war.

The improvement in triage which occurred in 1944–45 is evident in remarks made by Brig. Gen. (later Maj. Gen.) Joseph I. Martin, then Surgeon, NATOUSA, some years after the war (*12*):

> * * * The conflict that exists between the necessity of clearing the field of wounded and of bringing treatment and hope to those so badly wounded that they could not be moved reached a fine balance in the Fifth Army during the last year of the war in Italy. This efficiency was in great measure due to the professional zeal, devotion to duty, and judgment of the members of the 2d Auxiliary Surgical Group * * *. Their written record speaks for itself. It will constitute an excellent primer for the inexperienced military surgeon who will be faced with this problem at some future time.

Criteria of Transportability

When the general principles just described were fully established and properly followed, about 7 or 8 percent of all casualties passing through clearing stations reached field hospitals. When these principles were applied to thoracic casualties, in the light of the principles agreed upon at the meeting in Marcianise in March 1944 (p. 199), the majority of men with chest wounds, perhaps from 60 to 65 percent, were cared for in evacuation hospitals.

Since thoracic surgery as a specialty was of quite recent development, the criteria of transportability as applied to chest wounds were not clearly established at the beginning of the war and had to be clarified as the fighting proceeded. In some instances, the indications for holding patients in a field hospital were clearcut. A casualty with a thoracoabdominal wound, for instance, was always nontransportable. All decisions, however, were not so evident.

The chief reason for the original confusion was lack of realization of how well thoracic casualties tolerated transportation if cardiorespiratory disturbances were stabilized before evacuation. As a result, early in the war, many patients were operated on in field hospitals who could safely have been transported to the rear, while others were transported to evacuation hospitals before their cardiorespiratory balance was stabilized, and some of them lost their lives because of the error.

At the division clearing station, criteria for diverting casualties to the nearby field hospital included continuing hemorrhage; severe shock; sucking (blowing) wounds; wounds associated with respiratory distress of any degree; cardiac wounds; wounds of the trachea, esophagus, or large bronchi; and thoracoabdominal wounds, whether the diagnosis was established or merely tentative.

These indications, however, were not always absolute. For instance:

1. Continuing hemorrhage was more often from the chest wall and into the pleural cavity than it was external, and even persistent shock, rapid pulse, and low blood pressure were not always indications that bleeding was occurring. The shock might well be on a cardiorespiratory basis. In such cases, the diagnosis had to be established by repeated aspiration and the response to transfusion.

2. Sucking wounds [1] were numerous, because of the predominance of high explosive shell fragments as wounding agents, but the wounds were usually small, and the open pneumothorax was not in itself a common cause of respiratory embarrassment. A sufficiently large petrolatum-impregnated dressing served as an adequate corrective measure, accomplishing sufficient occlusion while at the same time providing an escape for air if a bronchial leak existed.

3. Both pressure pneumothorax and subcutaneous emphysema were surprisingly infrequent in the Mediterranean theater. The explanation was the size of the wounds, which were usually either too small to produce the phenomenon of an open pneumothorax or too large to seal off the escape of air under pressure. Another possible explanation was that preexisting pleural adhesions, which play a role in the mechanism of both these conditions, were uncommon in combat troops in World War II. Whatever the reason, these complications, which had been so frequent and so terrifying in the past, seldom furnished an indication for surgery in field hospitals in World War II.

4. Tracheobronchial obstruction was also not an absolute indication for surgery in the field hospital. It could be controlled by the use of a catheter or by bronchoscopic aspiration to clear the respiratory passages of blood and secretions. When these measures were combined with procaine hydrochloride (Novocain) block of the intercostal spaces involved in the wound, relief of pain was accomplished, and the patient was willing to cough frequently and thus achieve evacuation of his own tracheobronchial tree.

These and other cardiorespiratory disturbances, although they were frequent and urgent, did not require surgery in a field hospital. They could usually be controlled by the measures just outlined plus the ordinary routine of resuscitation.

The nontransportability of the casualty with a thoracic wound was not always caused by the thoracic wound. Multiple wounds were frequent, and it was often the severity of one or another of these, or their cumulative effect, which made it impossible to move him farther to the rear. In such cases, it was the usual rule to care for the thoracic wound before treating the others. Unless defects in the pleura were closed, the pleural cavity was evacuated of both blood and air, and the tracheobronchial tree was free of blood and mucus, the patient would be handicapped during the performance of the other procedures by incompetent respiratory function.

Air Evacuation

A significant part in the improved results of chest injuries was played by the increasing utilization of air evacuation in transporting patients to base hospitals from forward hospitals (p. 79). The comfort and speed of this method of evacuation undoubtedly hastened convalescence.

[1] Although the term "sucking wound" has the respectability that comes from long usage, actually, it is neither accurate nor descriptive. Any open pleural wound is potentially a sucking wound, but it does not suck in air all the time. What it really does is blow the air in and out, and for that reason, the term "blowing wound" would be more accurate and more truly descriptive. The use of the term "sucking wound" is continued in this volume merely because it is in general use.—T. H. B.

Routine evacuation of thoracic casualties by air was not possible. A high altitude flight in a nonpressurized plane, which involved respiratory strain, might prove harmful, or even fatal, if the chest wound was associated with any degree of preexisting respiratory difficulty. With careful selection, however, most casualties tolerated flights at from 4,000 to 5,000 feet remarkably well.

Numerous theoretical criteria were set up by which to gage the fitness of thoracic casualties for air travel, but experience in receiving, questioning, and evaluating patients showed that the necessary selectivity involved only a few practical points. Casualties with adequate stabilization of the cardiorespiratory mechanism, with a clear airway, without bronchopleural fistulas or sucking wounds, and without dyspnea, traveled well. Small to moderate pneumothoraces and hemothoraces, if static, were not contraindications to air transportation. Patients with empyema, who had been on open drainage for a short time, also traveled well if the mediastinum were stabilized. It was an additional precaution to be sure that no casualty was evacuated by air who had any appreciable degree of anemia.

Special Study of Evacuability

The following study of the evacuability of 113 consecutive casualties with penetrating or perforating thoracic and thoracoabdominal wounds was made by Major Shefts of the 2d Auxiliary Surgical Group (*12*). These patients were encountered between 15 January and 4 July 1944 and were examined immediately on admission to the 94th Evacuation Hospital. During this period, this hospital was variously located at Riardo, Mignano Monte Lungo, Anzio, Rome, Montalto di Castro, and Montepescali.

The distance which each casualty had been transported was considered to be the shortest distance between the geographic location of wounding, as far as it could be determined, and the location of the hospital at the time he was admitted. For a number of reasons, the distance traversed was often considerably longer than the estimated shortest distance. The average distance these casualties were transported was 22.2 miles, the range being 60 miles at one extreme and 5 miles at the other. The average lapsed time between wounding and arrival at the evacuation hospital was 8 hours, with the range from 34 hours to 30 minutes.

After careful clinical examination, the 113 patients were divided into two categories, the first based on the severity of their wounds and the second on their general status. The following data were obtained:

1. Of the 73 patients with severe wounds, 33 were received in good condition, 28 in fair condition, and 12 in poor condition.

2. Of the 40 patients with moderately severe wounds, 38 were received in good condition, 1 in fair condition, and 1 in poor condition.

3. These combined figures mean that 71 of the 113 patients were received in good condition, 29 in fair condition, and 13 in poor condition.

4. There were 7 deaths among the 113 patients, all after operation. One death occurred in the group classified as in poor condition and three each in the groups in fair condition and in good condition.

5. Five of the deaths occurred in the twenty-four patients with thoracoabdominal wounds, all of whom were classified as severely wounded. Two of the deaths occurred in the thirteen patients who arrived in good condition, and two in the eight who were in fair condition; the remaining death occurred in the three who arrived in poor condition.

On the Anzio Beachhead, where 73 of the 113 casualties were treated, the 94th Evacuation Hospital performed the functions of a field, not of an evacuation, hospital. Although the average mileage and elapsed time were nearly double at locations other than Anzio, the additional distance and lapsed time did not materially alter the condition of the casualties on hospitalization. From the clinical standpoint, those received at Anzio and those received elsewhere represented about the same proportions of good, fair, and poor risks, and substantially the same results were obtained in their management.

In view of these observations, it is not unreasonable to assume that most thoracic wounds can be safely treated in an evacuation hospital.

It is important to emphasize that the figures in this study and the conclusions drawn from them must be interpreted in the light of the criteria for thoracotomy in field hospitals set up at the meeting in Marcianise, in March 1944 (p. 200).

RESULTS OF THERAPY

The policies employed for the management of chest wounds during the Tunisian campaign were individualistic and unstandardized. The experience in Sicily was much the same. The establishment of the first chest center in the theater, at the 53d Station Hospital in Bizerte in July 1943, provided opportunities to evaluate the various policies employed to date, particularly the liberal use of thoracotomy. The evaluation left no doubt of the fallacy of this policy and of the far better results with conservative measures. These measures became standard policy after the meeting at Marcianise in March 1944.

For the last year of the war, therefore, there was a well-established, uniform policy for the management of wounds of the chest in the Mediterranean theater. The techniques employed had been known at the beginning of the war. Indications and contraindications had to be learned, however, as did timing and spacing of the necessary procedures. Still another important lesson that had to be learned was that the objective of resuscitation was to improve the casualty's condition to the point at which he could withstand surgery, which in itself was often the ultimate necessary purpose of resuscitation.

A comparison of the results of chest surgery before and after the new policies went into effect, after March 1944, left no doubt of the soundness of the change. That the results were related to the policies is quite evident, for the proportion of successful results overseas improved as the proportion of thoracotomies decreased.

The improvement in the condition of patients received in Zone of Interior hospitals was equally gratifying. An evaluation of the first 500 patients received at the Kennedy General Hospital chest center, Memphis, Tenn. (vol. II, appendix), was proof of the wisdom of conservatism in the management of thoracic injuries.

SPECIAL TYPES OF WOUNDS

Thoracoabdominal Wounds

Military manuals.—Thoracoabdominal wounds are not mentioned as such in War Department Field Manual 21–11, First Aid for Soldiers, 7 April 1943, although wounds of the chest and of the abdomen are both briefly mentioned. The material on thoracoabdominal wounds in War Department Technical Manual 8–210, Guides to Therapy for Medical Officers, 20 March 1942, is entirely derived from the manual on thoracic surgery prepared by the National Research Council.

National Research Council manual (*1*).—The concept of prompt surgery for abdominal wounds was firmly established by the end of World War I, and there was an almost equal realization of the importance of similarly prompt surgery in thoracoabdominal wounds. It is therefore surprising to find that in the manual on thoracic surgery prepared by the Subcommittee on Thoracic Surgery of the Committee on Surgery, Division of Medical Sciences, National Research Council, less than four pages are devoted to these wounds, which are termed "pleuro-abdominal" wounds. It is equally surprising to find the approach unexpectedly casual. Unless the injury is "compounded," the text states, repair "is usually not an emergency operation." There is a later discussion of the management of adhesions, whose presence, in themselves, would indicate that surgery had been deferred.

In substance, the material on thoracoabdominal wounds in the National Research Council manual is as follows:

1. First aid includes the administration of morphine; chemotherapy; the management of shock, including the administration of blood or plasma; and the immediate closure of a sucking chest wound.

2. Definitive treatment includes examination for abdominal injuries (the implication is that there are a large number of missed diagnoses, including rupture of abdominal viscera); excision of the chest wound; suture of the diaphragm; crushing of the phrenic nerve if the diaphragmatic injury is extensive; control of pulmonary hemorrhage by suture or resection; and tight closure of the chest wall, by use of the diaphragm if necessary.

3. Operation is always performed under intratracheal differential pressure anesthesia.

4. If the diagnosis of thoracoabdominal injury is made before operation, access could be transpleural or abdominal, depending upon the circumstances.

The abdominal route offers a satisfactory approach in early cases "without dense adhesions" and is quicker and easier for surgeons more accustomed to working in the abdomen than in the chest. The transpleural route, however, has its own advantages: When it is used, the pressure in the thoracic and abdominal cavities is immediately equalized, and it is thus easier to reduce the prolapsed abdominal viscera. Repair of the diaphragm is facilitated by lightly crushing the phrenic nerve with a hemostat, thus producing temporary paralysis, a maneuver which is simplified by the ready access to the nerve possible through the thoracic incision. Finally, intrathoracic adhesions between the prolapsed viscera and the lung can be divided under direct vision. Since these adhesions are often dense and troublesome, the thoracic approach is the approach of choice when the injury is "of more than a few weeks' standing."

If the preoperative diagnosis is rupture of a viscus, a median incision is likely to be used, prolonged to the xiphoid process. If the correct diagnosis of thoracoabdominal injury is made and a separate abdominal approach is used, the best exposure is provided by a left paramedian incision, extending from the xiphoid process to the umbilicus. If more exposure is required, it can be secured by cutting the left rectus muscle across at one of the transverse lines.

For right-sided injuries with lacerations of the liver, the subdiaphragmatic space is packed and drained. A posterior or lateral incision is used, with rib resection below the diaphragm if necessary. Left-sided injuries involving the stomach or spleen do not require abdominal drainage.

The entire discussion of thoracoabdominal wounds, in addition to being surprisingly casual, is also surprisingly incomplete. One of the notable omissions is the lack of any directions for the management of wounds of the colon, for which exteriorization or colostomy became the required treatment very early in the war.

Official directives.—As the war progressed, the thoracic approach to thoracoabdominal wounds became increasingly popular in the management of thoracoabdominal wounds in the Mediterranean theater, but no official policy to that effect was ever published. There is not a great deal, in fact, on the subject of these wounds in any of the official directives.

In an analysis of the management of the wounded in the Tunisian campaign (*5*), it was mentioned that in thoracoabdominal wounds, thoracotomy should be done in the field or the evacuation hospital, particularly if the wound was on the right. In a commentary on the care of the wounded in Sicily (*6*), it was stated that initial surgery should be performed in thoracoabdominal wounds in the field hospital. A sucking wound required priority, but otherwise, either the abdomen or the chest might receive first attention. In an occasional case, everything could be done through a thoracic approach. In other circular letters from the Office of the Surgeon, the official directives did not go beyond the instructions, repeated several times, to treat these patients as first priority, to be cared for in field hospitals.

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Cardiac Wounds

As related elsewhere (p. 44), cardiac surgery was no longer a clinical curiosity when the United States entered World War II. Nonetheless, the infrequency of wounds of the heart susceptible to surgical treatment—that is, of cardiac wounds not immediately fatal—is implicit in the scant attention paid to them in the instructions for their management issued during World War II.

Cardiac wounds are not mentioned in any of the circular letters published in the Mediterranean theater during the war. Nor are they mentioned in War Department Technical Bulletin (TB MED) 147 (*8*), dealing with the general care of battle casualties.

Apparently the only detailed instructions for the management of cardiac wounds during World War II appeared in the thoracic surgery section of the National Research Council manual published in 1943 (*1*). These instructions, like the rest of the material in the manual, were repeated in substance in TM 8–210. These instructions are as follows:

1. The usual first aid treatment should be instituted, including the use of blood or plasma in wounds associated with hemothorax, with a communication between the pericardial and pleural cavities. Replacement therapy is not mentioned in the management of cardiac tamponade.
2. Aspiration should be instituted in wounds associated with both hemothorax and cardiac tamponade, whether they have been caused by bullets or shell fragments.
3. Cardiorrhaphy should be performed if bleeding recurs.
4. Prompt open drainage should be instituted if purulent fluid is obtained from the pericardial cavity.
5. The management of foreign bodies in the heart and pericardium depends upon whether the objects have penetrated these structures directly or have been carried to them by venous channels. If they have entered directly, treatment should be directed to the wounds rather than to the foreign bodies. Postural methods should be employed, in an attempt to throw the object into the circulation, if it is in either ventricle, particularly the left ventricle, whose thick walls make palpation and identification quite difficult. If the object has entered the heart chambers via the circulation, postural methods are also employed. If they are contraindicated or are unsuccessful, conservatism is practiced. Whether or not the object is removed later depends upon whether or not it gives rise to symptoms. Then the risk of removal should be weighed against the severity of symptoms. Objects which are first free in the cardiac chambers and later become fixed should not be disturbed.

The technique of cardiorrhaphy is described in detail. The surgeon is warned that double wounds of the heart are not uncommon and that a wound of the anterior surface is an indication for inspection of the posterior surface.

THE SEVENTH U.S. ARMY

The policies for the management of thoracic (and other) casualties in the Seventh U.S. Army were generally those employed in the Fifth U.S. Army and base sections in the Mediterranean theater, many of whose surgeons were assigned to the Seventh U.S. Army before the invasion of southern France.

The general policies of surgical care of casualties, including thoracic casualties, were stated in Circular Letter No. 2 (*13*), dated 18 July 1944. These policies were reiterated in Circular Letter No. 17 (*14*), on 30 December 1944. The material in this letter was the same as the material in Circular Letter No. 46 (*7*), issued from the Office of the Surgeon, Headquarters, North African theater, in August 1944. This letter stated the policies for the management of chest injuries which had been agreed upon at the Marcianise meeting in March 1944.

The chief difficulty in new units, according to Colonel Berry, Consultant in Surgery, Office of the Surgeon, Headquarters, Seventh U.S. Army, was failure of their surgeons to realize the extreme importance of performing debridement according to fundamental principles. This was as true of chest wounds as of all other wounds. In theory, these new medical officers fully appreciated the necessity for debridement. In practice, they failed to abide by the theory.

In the Seventh U.S. Army, almost all casualties with wounds of the chest were sent first to field hospitals for examination, evaluation of their wounds, and such resuscitation as might be necessary. About 40 percent were then held in these hospitals for treatment.

Early in the Seventh U.S. Army experience, some surgeons believed that formal thoracotomy should be performed rather frequently at the time of initial debridement and that the official policy of conservatism would produce less good results. This was exactly the same state of affairs that had prevailed in the first days of the fighting in North Africa and Italy. As the campaign in southern France progressed, it became clear, just as it had in North Africa and Italy, that results were better and fatalities fewer when the official policy was strictly followed. When these patients were treated conservatively, they were usually well on their way toward regaining normal lung expansion and function by the time they reached evacuation hospitals. The results reported by general hospitals and observed in visits to them showed that these results were permanent and not ephemeral. As late as May 1945, however, it was necessary to issue another warning against the use of formal thoracotomy in forward hospitals, which had resulted in an increase of empyema (*15*).

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14. Circular Letter No. 17, Office of the Surgeon, Headquarters, Seventh U.S. Army, 30 Dec. 1944.

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CHAPTER VII

Emergency Measures

Lyman A. Brewer III, M.D.

The management of the casualty with a chest injury from the moment he was wounded until his arrival at a forward (field or evacuation) hospital was directed to the same end as was the management of all other wounded: To state it bluntly, it was to keep him alive until he reached an installation in which his wounds could be evaluated and suitable measures of resuscitation administered to make a safe candidate for surgery. There was often, however, a particular urgency about the care of thoracic casualties because their wounds seriously interfered with the physiologic function of respiration and had a secondary, often equally serious, effect on cardiac function.

MANAGEMENT ON THE BATTLEFIELD

Emergency care of the wounded was begun on the battlefield by company aidmen. The thorough training of these medical corpsmen, and of the battalion surgeons who received casualties from them, in the proper emergency measures to be applied in thoracic wounds is not susceptible of statistical analysis but was an unquestionable factor of real significance in the steadily improving mortality and morbidity of these wounds. Medical corpsmen were fully alert to the dangerous possibilities of chest wounds, particularly sucking wounds, and to the importance of their correct initial management. Forward surgeons were agreed that the number of patients with these wounds who arrived in forward hospitals without proper occlusive dressings steadily decreased during the war and was, on the whole, gratifyingly small.

Corpsmen were always instructed to do no more than was really necessary in any type of wound. In chest wounds, battlefield care was limited to several simple measures:

1. Open wounds of the chest (so-called sucking wounds) were closed in one of several ways (figs. 18 and 19). The simplest method was to occlude the wound with a gauze dressing, preferably petrolatum-impregnated, large enough and applied tightly enough to stop the characteristic blowing sound. Petrolatum-impregnated gauze was preferred to plain gauze for the first layer of the dressing, partly because it provided a more nearly airtight closure and partly because it could be more easily removed.

FIGURE 18.—Emergency packing of sucking chest wound by medical corpsmen.

The wound was not tightly plugged. The dressing was simply laid over it, and well beyond it, on all sides. It was held in place by adhesive straps. This simple measure usually proved entirely satisfactory. It eliminated the risk of an open pneumothorax during transportation to the rear and at the same time provided a means for escape of air under tension, so that tension pneumothorax could not develop.

Early in the war, it became the policy in the Mediterranean Theater of Operations, U.S. Army, to dress practically all wounds of the chest as if they were sucking wounds, as indeed many of them could become with changes of position (vol. II, ch. I).

2. Paradoxical motion of the chest, caused by multiple injuries of the bony thoracic cage (the so-called stove-in chest), was controlled by the snug application of a bandage.

3. Patency of the airway was maintained by urging the wounded man to cough. This measure was particularly urgent if his breathing was noisy or there was a rattle in his throat. Coughing could be encouraged if the corpsman could take the time to support the chest manually during the act.

4. A casualty who had difficulty in breathing when he lay recumbent was transported in a sitting or semisitting position if his condition and his other wounds permitted. The recumbent position often materially reduced the vital capacity.

5. Morphine was administered only if the patient was in real enough pain from thoracic or other wounds to make its use necessary (p. 244). A dose of gr. 1/4 was considered the maximum.

6. Associated wounds were given the required attention. If their severity warranted it, they were given precedence over chest wounds not associated with respiratory difficulties.

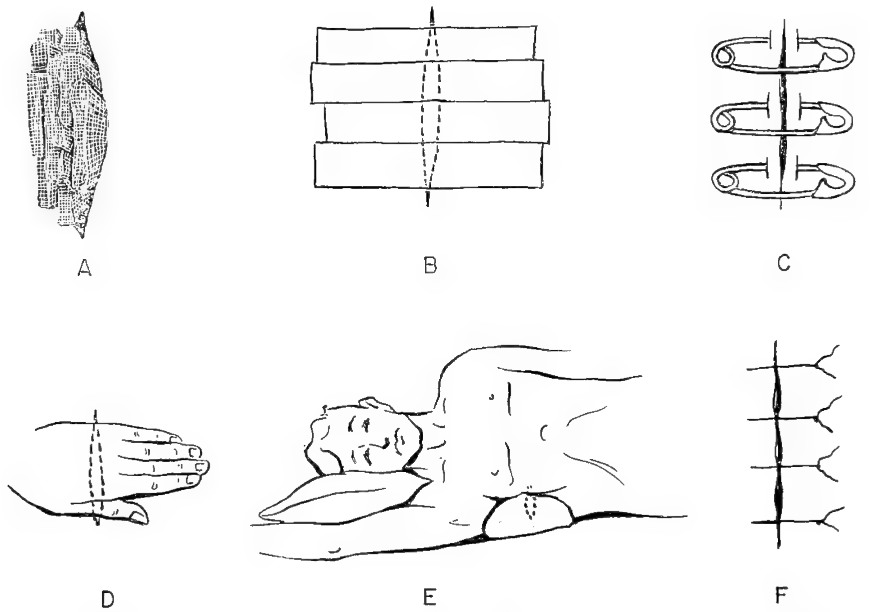

FIGURE 19.—Emergency management of sucking chest wound on battlefield or at battalion aid station. A. Occlusion of wound with cloth, plain gauze, or petrolatum-impregnated gauze. B. Approximation of wound edges with adhesive tape. C. Approximation of wound edges with safety pins. D. Manual approximation of wound edges. E. Positioning of patient on pad or pack so as to cover opening in chest wall. F. Temporary mattress suture of wound. This measure could be used only at the battalion aid station, as corpsmen were not provided with suture material and were not trained to insert sutures.

7. Early in the war, it was the policy to sprinkle sulfanilamide in all fresh wounds. As the war progressed, this measure was recognized as useless, if not actually harmful, and it was gradually abandoned.

Local chemotherapy.—At the beginning of the war, as described elsewhere, powdered sulfanilamide was part of the contents of the first aid kit, and the wounded soldier was taught to begin his own chemotherapeutic treatment, whenever he was able, by dusting his own wound with the powder. If he could not, the corpsman was taught to do it for him. Similarly, until almost the end of the war, sulfanilamide tablets were included in the first aid kit, and if the wound did not involve the abdomen, the soldier, if he was able, took them according to instructions as soon as he was wounded. Later, it

came to be realized that dusting an undebrided wound with sulfanilamide and covering it with gauze was no more than a gesture, and an ineffectual one at that.

MANAGEMENT IN BATTALION AID AND COLLECTING STATIONS

When the casualty arrived at the battalion aid station, he was observed by a medical officer, whose functions were:

1. To examine the dressings over the wound, making sure that they were properly applied and readjusting them as necessary. If they had become stiffened by blood, they had frequently ceased to be airtight and had to be changed. Dressings over large sucking wounds were examined with particular care. Unless circumstances required it, however, dressings which had been applied satisfactorily were simply inspected; they were not changed.
2. To administer morphine if it were really needed for pain and if it had not been given by the company aidman (p. 244). Intravenous administration was preferred in patients in shock.
3. To begin a plasma transfusion if the patient were in shock or seemed to be verging on shock. From the most forward point, care was taken not to overload the circulation of a thoracic casualty.

At the beginning of the war, it was the practice of some medical officers to dust the wound with sulfanilamide crystals at battalion aid stations. The practice was never uniform, and eventually it was discontinued. It was never useful.

When penicillin became generally available, in the spring of 1944, it was given in the battalion aid station or the clearing station, in the amount of 20,000 units intramuscularly every 3 hours.

At the collecting station, the next point of medical care within the division, the same procedures were employed. Dressings were inspected carefully, but they were not adjusted or changed unless circumstances required it (fig. 20). It was often difficult to persuade inexperienced medical officers to obey these instructions.

MANAGEMENT IN THE CLEARING STATION

Once the casualty reached the divisional clearing station, he was subjected to triage (sorting) to determine his further management (p. 202). His disposition depended upon the character and severity of his injuries and the urgency of surgery for them, his physical status, and the number of other casualties and the urgency of their wounds.

A casualty whose wounds were slight and who could probably be returned to duty promptly was held in the clearing station. Early in the war, a casualty who was in shock, regardless of the kind of wound he had sustained, was treated for it at the clearing station, and his disposition was determined after resuscitation. Later, it became the policy to send all patients in shock,

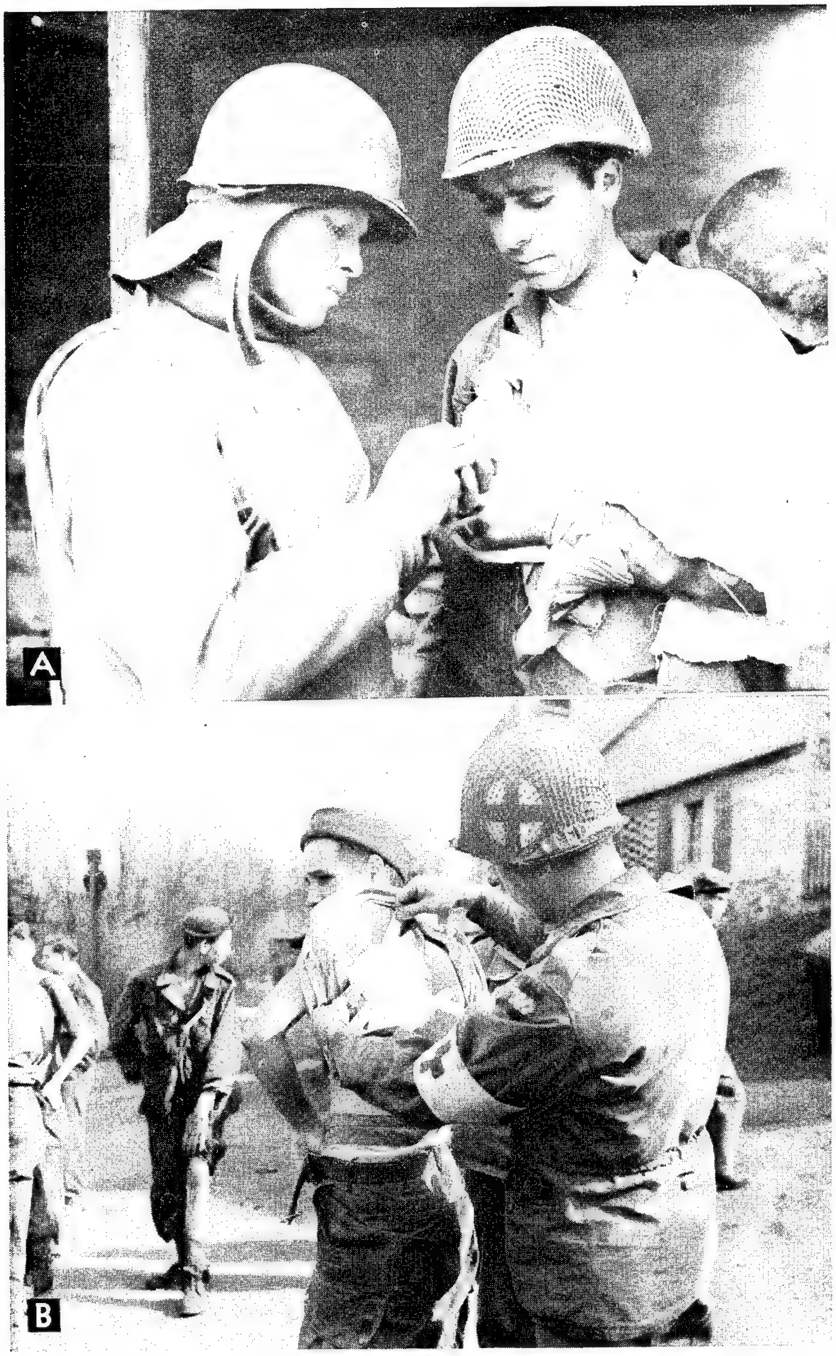

FIGURE 20.—Adjustment of surgical dressings on ambulatory chest casualties at collecting station. A. Adjustment of dressings on anterior wound. B. Adjustment of dressings on posterior wound.

regardless of the kind of wounds they had sustained, to the shock ward of the adjacent field hospital and to determine their further disposition there.

Whether or not he was in shock, a casualty who required urgent surgery, which the majority of casualties with thoracic injuries did not, was always sent to the field hospital. Otherwise, he was evacuated to an evacuation hospital for initial wound surgery.

The clearing station was the farthest forward point at which whole blood was available for transfusion. The policy was to administer it here to patients who, it was thought, would then be safely transportable to an evacuation hospital.

TRANSPORTATION

From the time he was picked up on the battlefield, the wounded man was transported to the rear as rapidly as possible until he reached the clearing station, where the plan of management he required was determined upon. The timelag from injury to triage varied according to the combat activity of the division, the number of casualties, and the terrain over which they had to be moved. Sometimes, it was a matter of minutes. More often, it varied from 2 or 3 hours to 15 hours or more. Occasionally, when the tactical situation was particularly difficult, it was 24 hours or more.

Casualties with superficial wounds of the chest were permitted to be ambulatory. All other thoracic casualties were carried. They were usually moved by litter from the battlefield, though during the fighting in the Apennines, as already mentioned, they were frequently brought down the mountain by mules. Movement from the battalion aid station to the collecting station, depending upon the tactical situation and their relative locations, was by litter, by jeep with improvised litter racks, or by ambulance. Transportation from the collecting station to the clearing station was usually by ambulance. The clearing station and the field hospital were so closely adjacent that casualties were moved from one to the other by litter carry.

CHAPTER VIII

Diagnosis

Lyman A. Brewer III, M.D.

GENERAL CONSIDERATIONS

Refinements of diagnosis in thoracic injuries (and all others) were deferred, as a practical matter, until the patient had reached the field or evacuation hospital in which initial wound surgery was to be carried out. Up to that point, all that was necessary for the care of the patient was the general information that he had a wound of the chest which was or was not sucking and in which hemorrhage was or was not a factor.

When the casualty arrived in a field hospital, a preliminary appraisal was made of his wounds and of his general status. His pulse, respiration, and blood pressure were determined immediately and recorded. If he was in shock, or seemed to be verging on shock, resuscitative measures were instituted at once, to prepare him for surgery or to make him safely transportable farther to the rear.

The dressing was checked, to make certain that the wound was not sucking and bleeding was not active. Then, if the patient was in shock or was thought to be verging on shock, diagnostic measures were discontinued and resuscitative measures (p. 241) were instituted at once. The manner in which he reacted to these measures often aided considerably in the determination of his disposition. Many times, after pain had been relieved and vital capacity improved, it became evident that transportation farther to the rear could be safely undertaken. In other instances, when no improvement occurred or when a period of temporary improvement was followed by regression, it became equally evident that operation was an essential part of resuscitation and must be undertaken without delay.

Aside from the fact that resuscitation, from the lifesaving standpoint, was frequently imperative, anything but a tentative diagnosis was often difficult, if not actually impossible, until the casualty had been brought out of shock and his impaired cardiorespiratory balance had been improved or entirely corrected. A soldier admitted to a shock tent groaning with pain, dyspneic, cyanotic, and hypotensive, did not lend himself to examination or appraisal. An experienced chest surgeon, however, or even a considerably less experienced medical officer on a shock team, usually had little difficulty in arriving at a precise diagnosis and making a decision as to the urgency of surgery after such resuscitative measures had been employed as forced coughing, endo-

tracheal catheterization or bronchoscopy, replacement therapy, thoracentesis, and intercostal nerve block.

There were five main points to be considered in the diagnosis of a thoracic wound:

1. The course of the missile and the probable direct damage that it had done.
2. The possible blast effect of the missile.
3. The presence or absence of signs of a completely or partially obstructed airway.
4. The presence of a sucking wound.
5. The presence and degree of pulmonary compression caused by air (pneumothorax) or blood (hemothorax) in the pleural cavity.

While it was frequently impossible, it was always desirable that casualties with thoracic injuries, both before and after operation, should be kept away from the noise of gunfire. The apprehension created by it increased dyspnea and had other bad effects.

HISTORY-TAKING AND PHYSICAL EXAMINATION

History-Taking

History-taking in the manner in which it was usually practiced in civilian medicine was not possible in military medicine, partly because there was no time for such a detailed inquiry and partly because the casualties were, for the most part, in no condition to endure it. It was an invariable rule not to question any patient who was seriously wounded or who was in shock or verging on it until he had been sufficiently resuscitated for the questioning to impose no additional strain on him. If it was possible, however, it was important to learn the position of the patient when he was wounded, for this information helped to clarify the probable course of the missile through the body and its final resting place. It was also important to learn how near the patient was to the actual site of a shell explosion, so that its blast effects could be estimated.

Multiplicity of Wounds

Careful examination of the entire body was a matter of the greatest importance. Serious diagnostic errors, and consequent errors of management, could result if the attention were concentrated on a single wound, however obvious it might be. The associated wound was sometimes more serious than the chest wound and might require more radical surgery (fig. 21).

Wounds of the abdomen were sometimes a part of the thoracic wound and sometimes independent of it. Spinal cord injuries were frequently associated with chest injuries (vol. II, ch. I). Associated wounds of the arm and shoulder

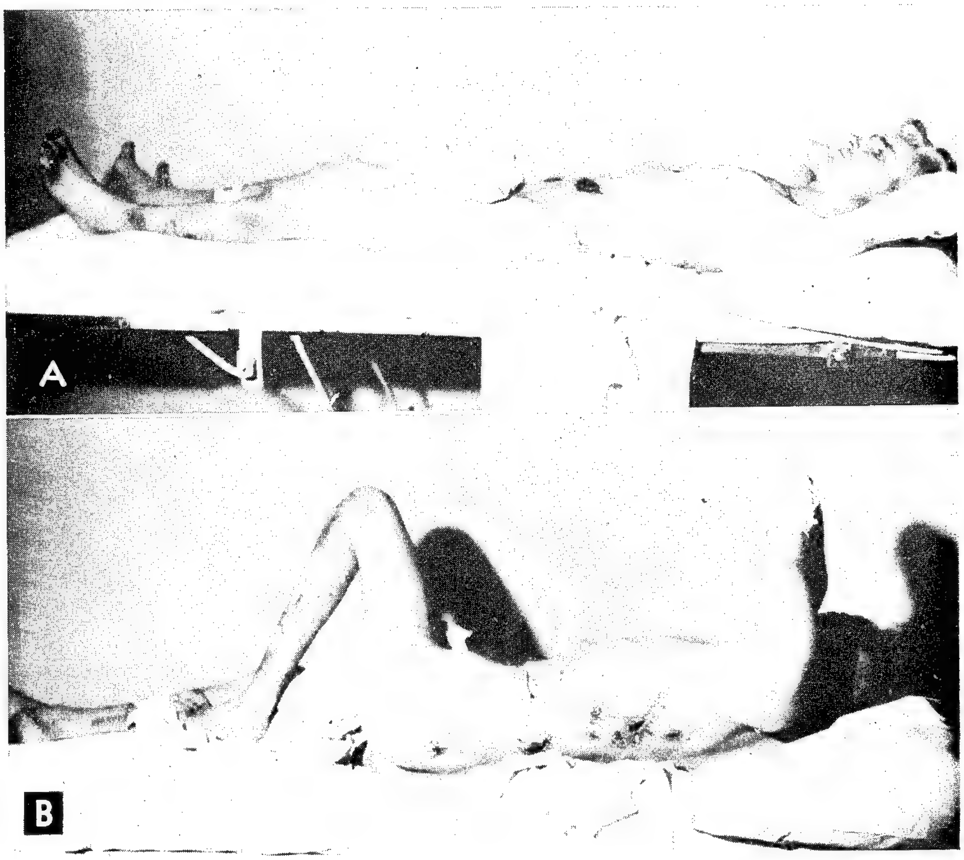

FIGURE 21.—Chest casualty with multiple other wounds, including an injury of the buttock for which colostomy was necessary. The pictures were taken in a base hospital, after closure of the wound of the chest wall. A. Patient recumbent. B. Patient in left lateral position.

were also frequent, and some chest wounds were sometimes overlooked because of the more conspicuous perforating wounds of the upper arm. It was particularly important in injuries of the arm and shoulder that complete chest roentgenograms be made.

Multiplicity, in short, was a factor which influenced every phase of chest injuries, from battlefield management to disposition, and it accounted for a certain rather sizable proportion of the fatalities in such injuries. Multiple wounds, as might be expected, were particularly notable in battlefield deaths (figs. 22, 23, 24, 25, 26, and 27). In the study of a thousand such deaths made by Capt. William W. Tribby, MC, in Italy in 1944 (*1*), there were only 312 cases in which the wounds were not multiple. In the 572 wounds of the chest included in the series, the wounds were limited to the chest in only 84.

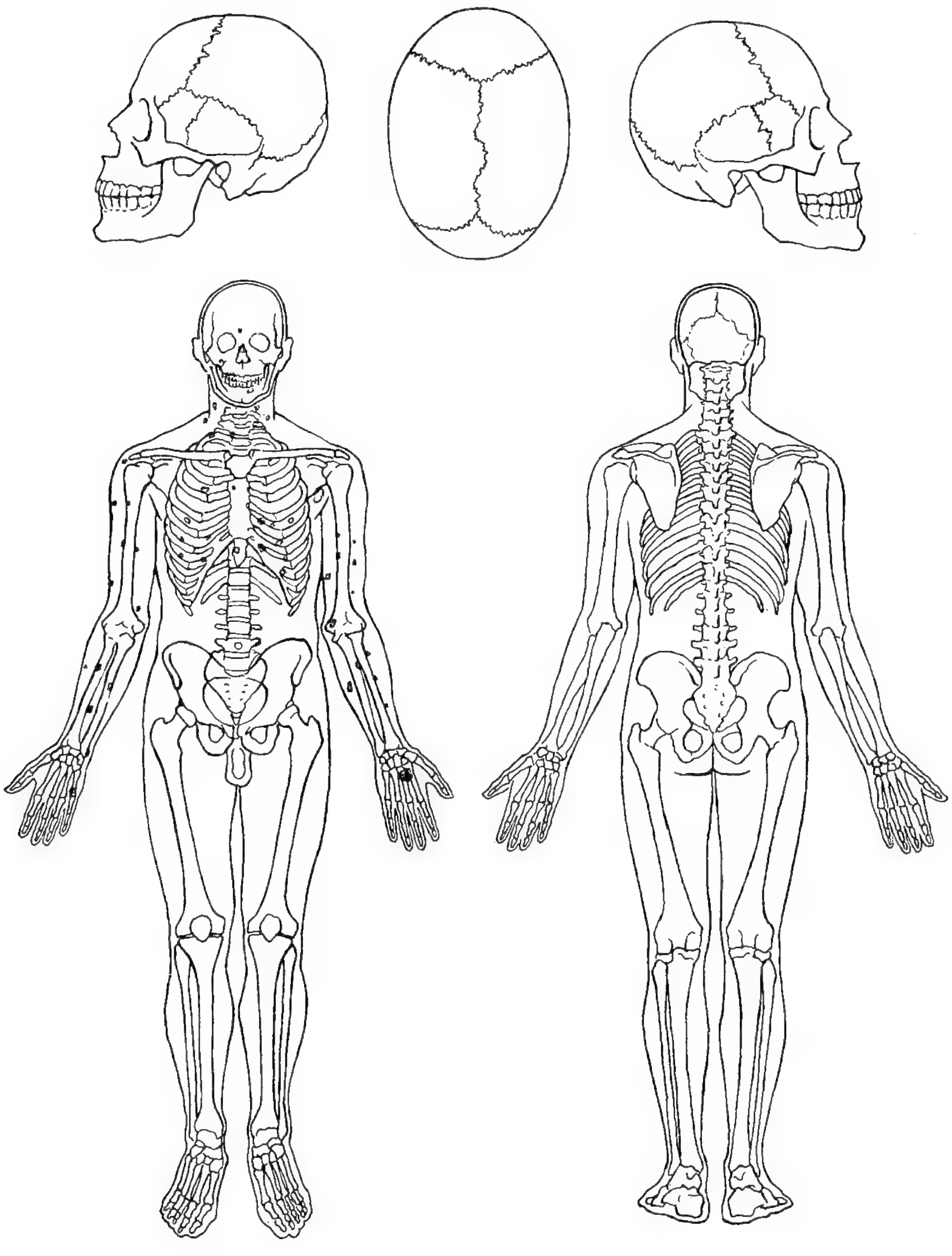

FIGURE 22.—Diagrammatic showing of multiple wounds of head, neck, chest, and both upper extremities caused by shell fragments (mortar). Many small penetrating wounds are present in the face, neck, chest, and both arms. The largest wound, 2 by 3 cm., is in the left anterior axillary line near the shoulder; its track perforates the thoracic wall. (Redrawn from Tribby, case No. 17.)

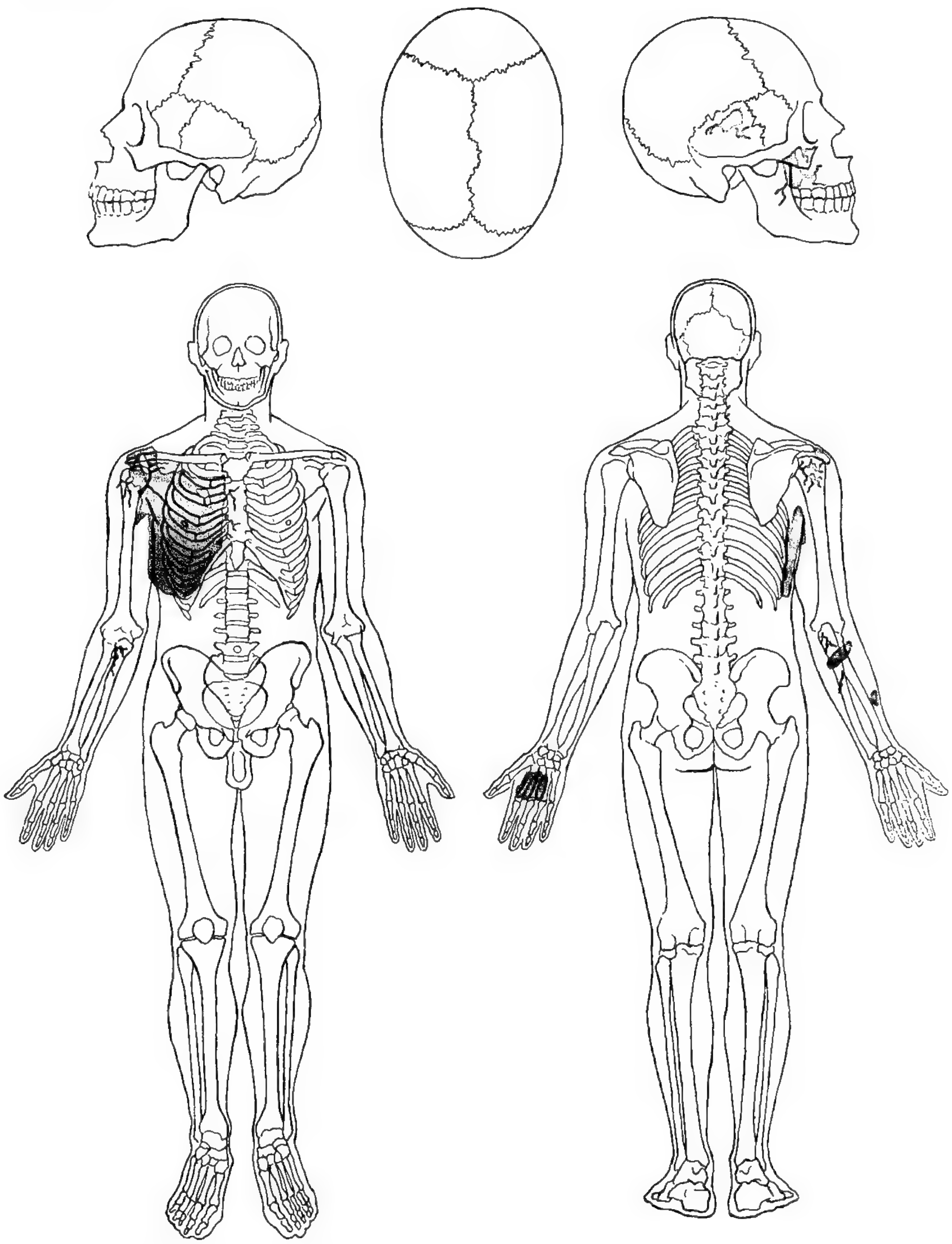

FIGURE 23.—Multiple wounds, head, chest, and upper extremities, caused by shell fragments. Penetrating wounds, one above right ear and one in right cheek, 1 by 1.5 and 2 by 6 cm. Right side of chest shows a crushing injury with partial evisceration of lung and fractures of ribs and sternum. Right axillary region mutilated, with a compound comminuted fracture of upper end of humerus. Through-and-through wound in right forearm, with a compound comminuted fracture of ulna; lateral point of entry, 1 by 2 cm.; posterior point of exit, 2 by 5 cm. Wound of left hand, 3.5 by 6 cm., shows a compound comminuted fracture of second metacarpal bone. (From Tribby, case No. 58.)

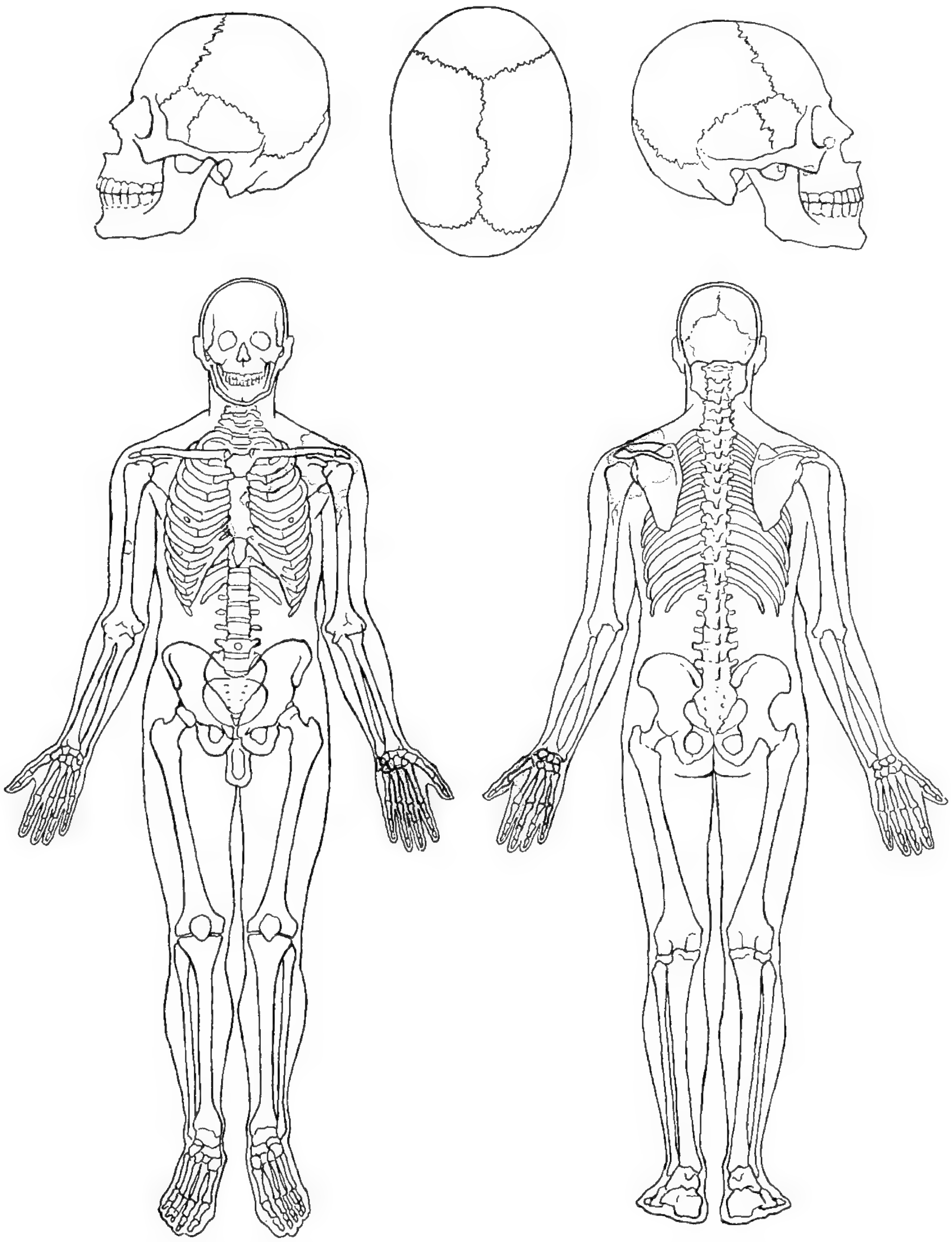

FIGURE 24.—Multiple wounds, head, chest, and both upper extremities caused by high explosive; penetrating wound, 1.7 cm. in diameter, located below left eye; two penetrating wounds, 1 cm. and 1.5 cm. in diameter, in right cheek; anterior wound enters cranial cavity. Four penetrating wounds in anterior chest vary from 1 cm. to 3 by 6 cm.; all four wounds enter thoracic cavity, largest in left upper chest. Left shoulder is mutilated, with compound comminuted fracture of proximal end of humerus; severe mutilation of left hand; penetrating wound, 1.5 cm. in diameter, in right arm in middle of biceps muscle. (From Tribby, case No. 105.)

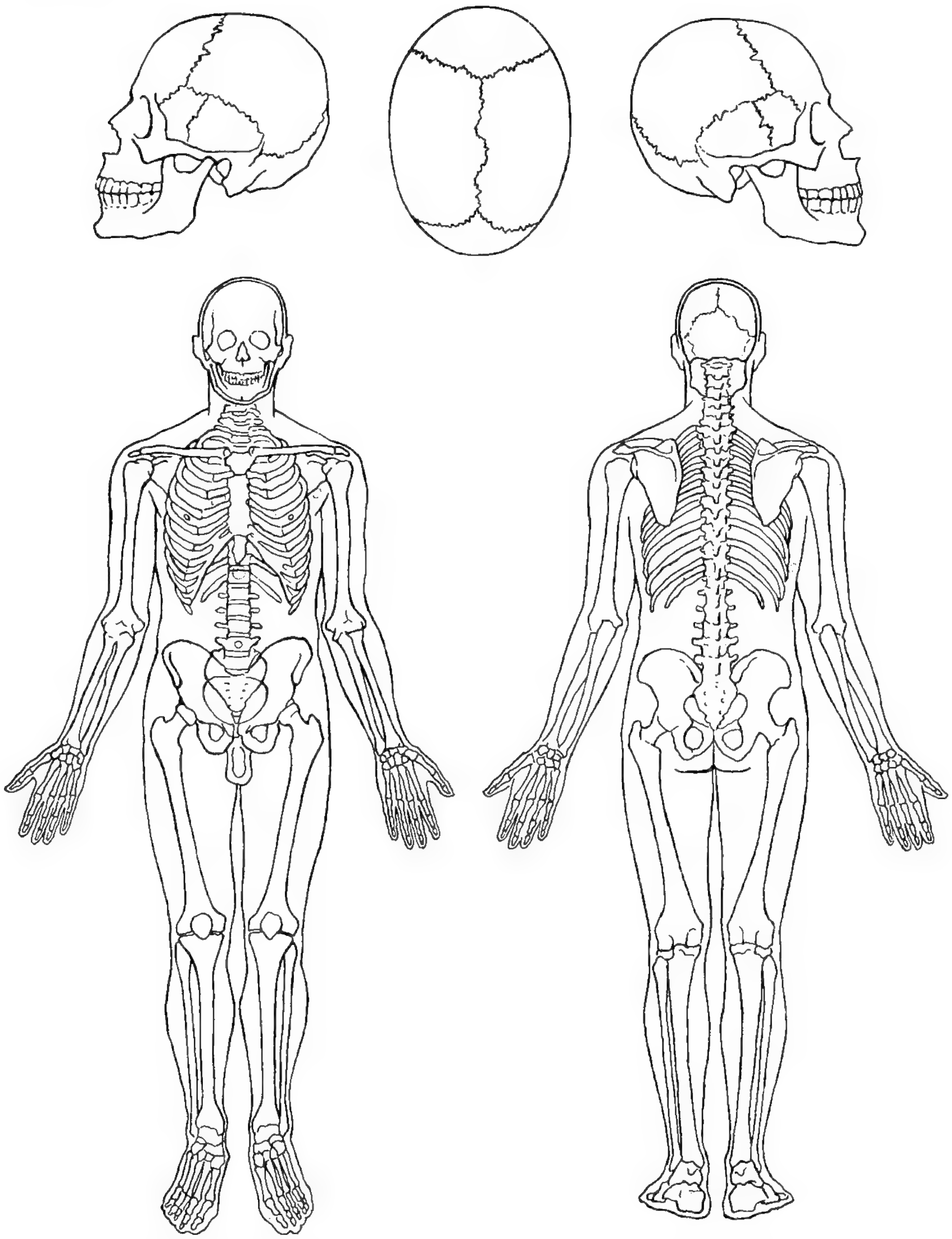

FIGURE 25.—Multiple wounds, chest and abdomen, caused by high explosive. Wound, 1 cm. in diameter, perforates thoracic wall in anterior left side, in anterior axillary margin at level of first rib. Wound, 1 cm. in diameter, enters thorax in anterior right side at margin of sternum through third intercostal space. Wound, 1.5 by 2 cm., enters thorax in anterior right side in anterior axillary line, level of eighth intercostal space; penetrating wound, 7 mm. in diameter, lateral right side of chest, posterior axillary line, level of eighth intercostal space. Wound 1.2 cm. in diameter, perforates abdominal wall in midline of epigastrium near tip, xiphoid process. (From Tribby, case No. 513.)

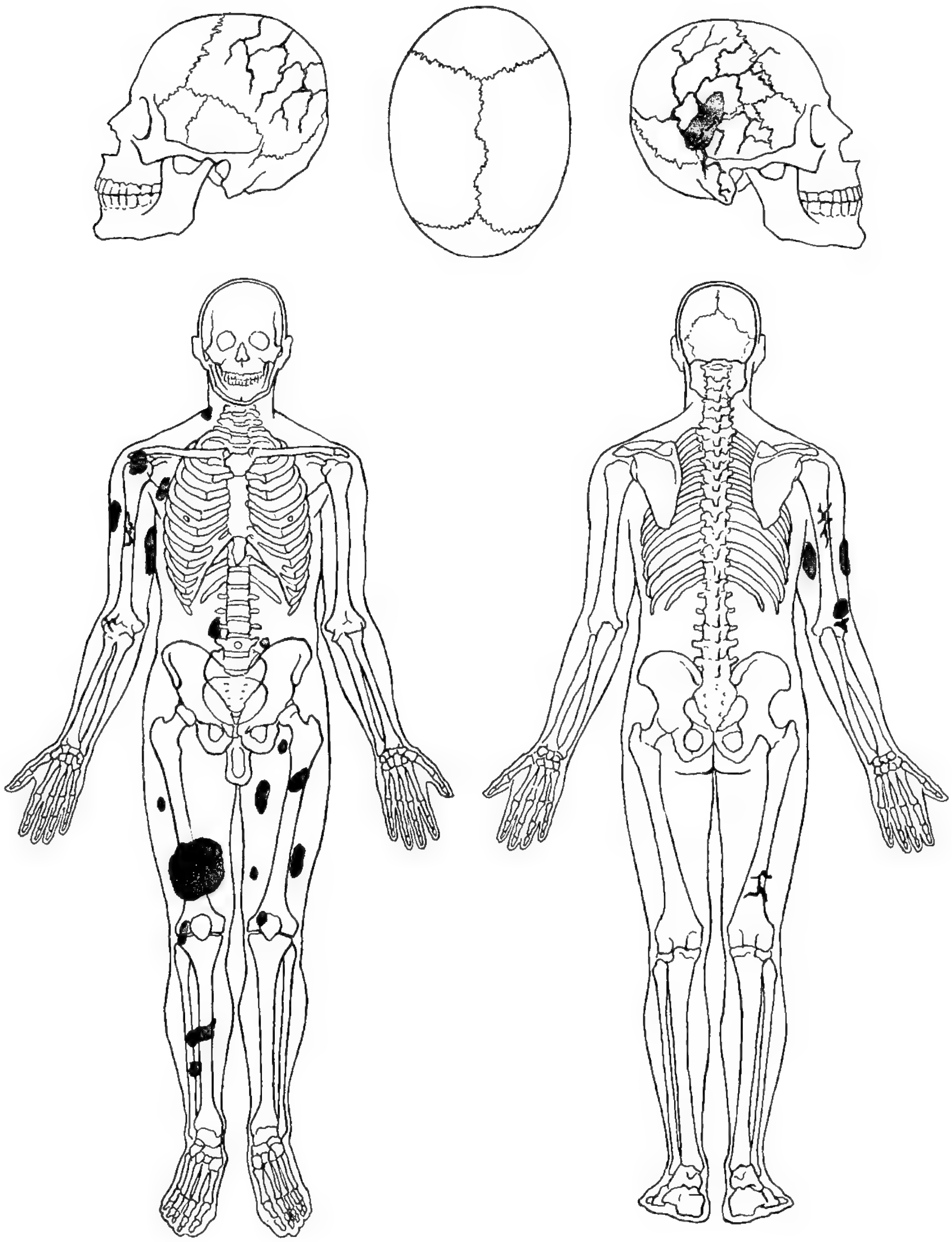

FIGURE 26.—Diagrammatic showing of multiple wounds of head, neck, chest, abdomen, right upper extremity, and both lower extremities caused by shell fragments. There is a penetrating lacerated wound, 4 by 10 cm., in the right posterior side of the skull in the region of the squamous suture; both parietal bones, the occipital bone and the right mastoid bone, are extensively crushed. A penetrating wound, 2 cm. in diameter, enters the base of the neck in the right lateral side. A penetrating wound, 2 by 3 cm., in the right mid chest area in the anterior axillary line enters the thoracic cavity through the fourth intercostal space through a transverse fracture of the fourth rib. A through-and-through wound is present in the lower abdomen; the point of entry, 2 cm. in diameter, is in the left lower quadrant, and the point of exit, 4 cm. in diameter, is in the right side near the umbilicus. A wound, 4 by 6 cm., penetrates the right anterior shoulder without a palpable fracture. A through-and-through wound in the proximal third of the right mid arm reveals a compound comminuted fracture of the humerus; the point of entry is located laterally and measures 10 cm. in diameter; the point of exit is located medially and measures 12 cm. in diameter. A penetrating wound, 5 cm. in diameter, in the right distal arm, exposes a compound comminuted fracture of the lateral epicondyle of the humerus. There are several large lacerated, penetrating wounds in both anterior thighs, in the knees, and in the right mid leg. The largest wound is in the distal anterior right thigh and measures 20 cm. in diameter; there is a compound comminuted fracture of the femur in this latter wound. (Redrawn from Tribby, case No. 465.)

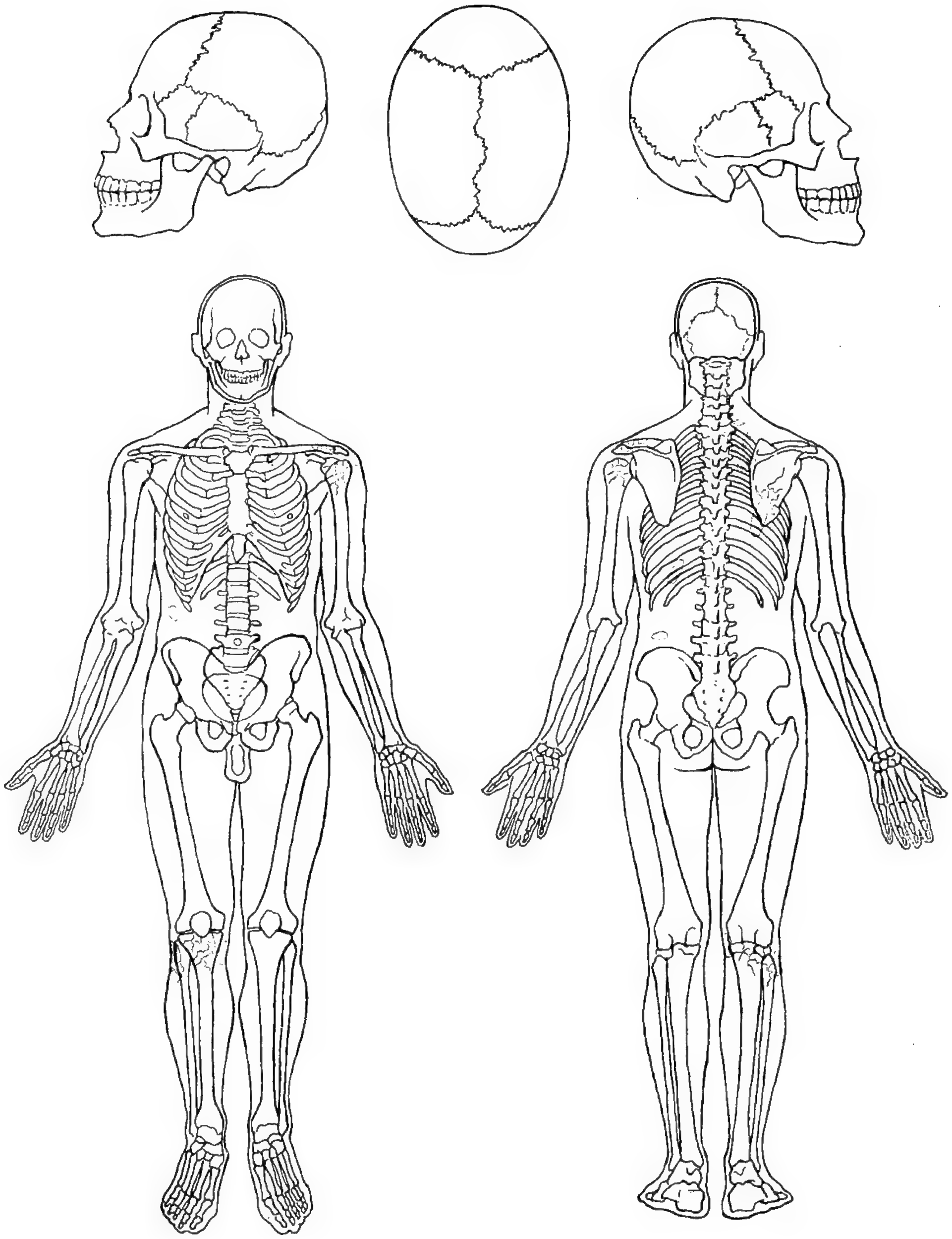

FIGURE 27.—Diagrammatic showing of multiple wounds of neck, chest, abdomen, and left upper and right lower extremities caused by high explosive. A penetrating wound, 2 cm. in diameter, is found in the tip of the left shoulder. The track extends downward and medially and enters the left side of the thorax. There are comminuted fractures in the head of the left humerus and in the lateral end of the clavicle, in the acromion process of the scapula, and in the first rib. Four lacerated penetrating wounds are present in the posterior right side of the neck and chest between the levels of C7 and T4. The largest wound, 4.5 by 8 cm., is near the inferior angle of the right scapula. There are compound comminuted fractures in the first four ribs, in the right scapula and in the body of T2. A superficial lacerated wound, 3 by 5 cm., is present in the lower posterior left side of the chest. A wound, 1 by .5 cm., enters the abdominal cavity above the posterior left crest of the ilium. A penetrating wound, 2.5 cm. in diameter, enters the abdomen in the right flank near the tip of the eleventh rib. There is a through-and-through wound in the proximal end of the right leg adjacent to the knee joint. The medial opening measures 3 by 4 cm., the lateral opening, 3 by 5 cm. The proximal ends of the tibia and fibula are severely comminuted. (Redrawn from Tribby, case No. 580.)

Methods of Physical Examination

Physical examination was carried out after the clothing had been cut away and removed, to avoid the possibility of overlooking associated wounds. Wounds that were adequately dressed when the casualty was received in the field hospital were not disturbed until it was possible for both the chest surgeon and the shock officer to examine them together. Multiple inspections were avoided. They invited infection and, if a sucking wound was present, permitted the further entrance of air into the pleural cavity. Examination included the head, neck, and extremities, as well as the chest, back, lumbar area, and abdomen, to insure that a small wound of entrance or any source of hemorrhage was not overlooked.

Experience showed that in the circumstances that prevailed in a field hospital, a gross physical examination offered more useful information than could be obtained from more refined methods applicable in civilian practice. For example, a check of the position of the trachea in the suprasternal notch or of the position of the apex cardiac impulse gave as much evidence, and sometimes more evidence, of the presence of a clinically significant hemopneumothorax than did time-consuming percussion and auscultation, measures that were often difficult to carry out in a busy, noisy resuscitation ward. Minor deviations from the normal, such as would have been found by more refined methods of diagnosis, were seldom of particular significance in the plan of management.

Projection of the Course of the Missile

Physical examination was carried out by the usual routine, supplemented by accurate localization of the external thoracic wound or wounds and by projection of the probable course of the missile, beginning with the information provided by roentgenologic examination. It was necessary to take into consideration the location of the external wound or wounds, to identify fractures of the ribs, and to visualize any metallic fragments which might be present. It was also necessary, when possible, to determine the patient's position at the time of wounding.

As a general rule, missiles traveled in a fairly straight line, but if they struck the bony thoracic cage, deflections were to be expected. The voluminous literature on the erratic course of missiles within the body has always tended to put too much emphasis on the exceptional case in which the missile, because it struck a rib or some other bony structure and was reflected from it, failed to take the usual straight course.

Foreign bodies lying free in the pleural cavity could be quite misleading. In one such case, no wound of entrance could be found, and the only associated wound was over the deltoid tubercle. When the patient was asked about his position at wounding, he said that he was lying on the ground, with his arm extended upward alongside his head, when he was injured (fig. 28). This was

only one of many cases in which, when the facts were secured, the course of the missile ceased to be mysterious.

If the patient's condition permitted, it was always best to move him to a clean litter before roentgenologic examination. In more than one case, a foreign body which lay free on the litter was sometimes erroneously thought to be in the body.

Details concerning the localization of retained foreign bodies appear under that heading (vol. II, ch. VII).

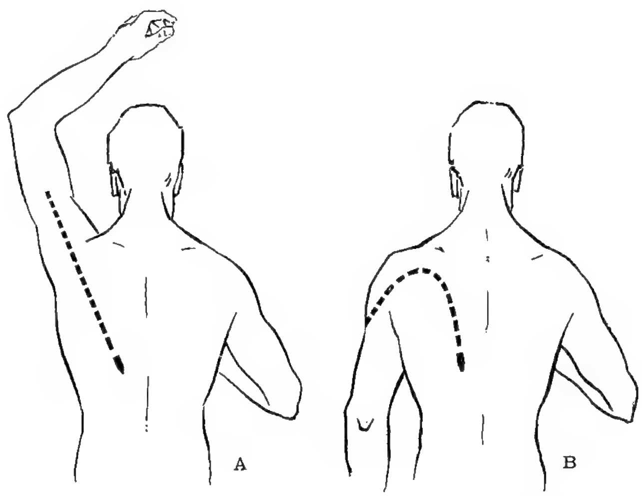

FIGURE 28.—Diagrammatic showing of apparently bizarre course of missile, with only wound of entrance over deltoid tubercle. A. Course of bullet at wounding, when patient was lying with left arm extended above his head. B. Course with arm at side.

CLINICAL PICTURE

Symptoms

Among the points on which the casualty with a chest wound was questioned when time and circumstances, including his own status, permitted were the following:

1. His chief complaint. This was not always related to the obvious wound or wounds, and such an inquiry sometimes directed attention to a wound which had not been entered on the emergency medical tag.

2. Pain, including its type, location, and relation to respiration. Pain of some degree was the rule in thoracic wounds, although its intensity was frequently dulled by morphine before the patient was received in the field hospital. It was often located in the chest wall, but pleural pain was a definite

entity. Even if the wound was limited to the thorax, it was frequently associated with abdominal pain and tenderness.

3. Dyspnea, including its onset in relation to wounding and whether it was increasing or decreasing. True shortness of breath implied deficient oxygenation, and, in the absence of severe blood loss, was usually attributable to decreased function of the pulmonary parenchyma. Among the conditions which could contribute to it were hemothorax, pneumothorax, and hemorrhagic infiltration of the lung. A history of increasing dyspnea suggested increasing pressure on the lung by blood or air.

4. Whether blood had been coughed up, and, if so, when the episode had occurred in relation to wounding and how copious the hemoptysis had been. Hemoptysis of some degree could be expected in almost all penetrating wounds of the chest. It was also common in severe wounds of the thoracic wall, in contusions of the lung, and in blast injuries. Hemoptysis was always a warning sign, though the amount of blood coughed up varied with the particular wound and was not correlated with its severity.

5. Nausea and vomiting, in relation to the time of wounding and the time of the last meal before wounding. Nausea and vomiting were not commonly associated with wounds limited to the thorax, but they occasionally occurred. In at least one instance, they were present in a wound of the heart (vol. II, ch. II). Frequently, however, these manifestations were related to the stress and strain of combat conditions, under which undigested food might remain in the stomach for many hours, to be ejected under the additional stress of wounding.

6. Any period of unconsciousness, and, if it had occurred, how long it had lasted. A short period of unconsciousness was not infrequent in injuries caused by high explosive shells. Longer periods, especially if the casualty had previously been fully conscious and oriented, were more likely to be caused by shock, severe blood loss, cerebral concussion, or cerebral damage from prolonged anoxia. Maniacal manifestations, which were sometimes observed, always indicated severe anoxia.

The clinical picture of severe shock in a thoracic casualty was sometimes the result of loss of blood by the usual routes but was sometimes the result of a rapid decrease in the vital capacity caused by pulmonary collapse from bleeding into the pleural cavity, with mediastinal shift. This picture might also be produced by the reduced respiratory excursion resulting from pleural pain, most often caused by fracture of the ribs.

7. Sucking (blowing) of the wound. A story of sucking or exchange of air through the wound was presumptive evidence that the missile had penetrated the pleura. The same observations were occasionally made in extensive soft-tissue lesions without pleural involvement, especially if the chest wall was flaccid as the result of multiple rib fractures. The presence or absence of sucking had no bearing on the course of the missile or on the damage it might have done.

8. The wounding agent, the patient's position at the time of wounding, and his distance from the high explosive shell or other missile.

9. Whether the time of wounding, as far as the patient knew, corresponded with the time recorded on the emergency medical tag.

A quick runthrough of these questions, which could be asked as the physical examination was proceeded with, often provided a surprising amount of useful information. It also played a part in establishing the physician-patient relation so often necessarily, but always unfortunately, lacking in medicomilitary circumstances.

Signs

General considerations.—The general appearance of the patient, including his color, was more important than the physical signs elicited in the chest. If cyanosis and dyspnea of any degree were present, it had to be assumed that the cardiorespiratory mechanism was out of balance. Cyanosis was always a sign of comparatively advanced anoxia. Even under these circumstances, however, it was not always present: If there had been severe blood loss, cyanosis might not be detectable because of the lower hemoglobin content of the blood. It could be missed in poor light.

The type and character of the respirations were important. Patients with badly contused lungs from direct injury or from blast often exhibited the signs of wet lung (vol. II, ch. V). Rapid, rattling respirations, with frequent, ineffectual coughing, were clear evidence of difficulty in maintaining a patent airway.

Chest findings.—Both cyanosis and dyspnea indicated the necessity for careful examination of the chest for signs of pressure pneumothorax, a large hemopneumothorax, or an incompletely sealed sucking wound. Any perforating or penetrating wound of the chest of any consequence necessarily resulted in the entrance of at least a small amount of blood or air or both into the pleural cavity. Small amounts did not materially influence the cardiorespiratory mechanism, but when either was present in sufficient quantity to restrict lung expansion, adequate oxygenation could not occur. Physical signs could be most misleading in estimating the size of the pleural collection, and the severity of symptoms was often entirely unrelated to the amounts of fluid or air detected on physical examination.

Unilateral rigidity of the chest wall was frequently associated with hemothorax, but its absence was of no diagnostic significance.

Abdominal findings.—Careful examination was carried out in all thoracic injuries to determine whether the wound was thoracoabdominal or whether a separate abdominal wound was also present. Abdominal examination in all chest injuries was also required for other reasons:

1. A large number of patients with uncomplicated thoracic injuries developed acute gastric dilatation soon after wounding, though many times it was not apparent until roentgenologic examination was carried out (vol. II, ch. IV). Gastric dilatation increased respiratory difficulties and was an indication for immediate decompression by nasogastric suction.

2. Even a wound limited to the thorax was frequently accompanied by abdominal pain, tenderness and rigidity (the phrenodiaphragmatique rigidity

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referred to by French writers). The abdomen might be completely silent. The origin of these symptoms and signs has never been fully explained. Irritation or injury of the intercostal nerves and diaphragm did not seem to cover all cases. The picture was further confused by the fact that in some intra-abdominal injuries, especially if only the spleen or the liver was injured, physical findings soon after wounding might be very slight.

Differentiation between thoracic wounds accompanied by abdominal findings and thoracoabdominal wounds was frequently difficult, but it was imperative to lose no time in making it. As a rule, the abdominal spasm which accompanied a thoracic wound tended to be unilateral and to become less evident upon inspiration, while spasm caused by an abdominal injury tended to be bilateral. Anesthetic block of the intercostal nerves in the involved areas sometimes furnished useful diagnostic aid. If pain and cutaneous tenderness disappeared after the block, it could be concluded that the wound was limited to the chest. If some degree of spasm, rigidity, and tenderness on deep pressure persisted in spite of the nerve block, it could be concluded that an abdominal injury was present in addition to the thoracic wound. This was a time-consuming method, which would not be used in patients in poor condition.

The correct interpretation of clinical symptoms and physical signs was most important in patients whose condition was too precarious to permit roentgenologic examinations until extensive resuscitative measures had been employed.

Details of the diagnosis of thoracoabdominal wounds are discussed under that heading (vol. II, ch. III).

ROENTGENOLOGIC DIAGNOSIS

X-ray facilities, as already mentioned, were somewhat limited during the North African campaign, and a field hospital had only a single apparatus for its three platoons. This situation was remedied before the invasion of Italy, and thereafter each platoon had its own machine and accessories.

An essential part of the preoperative routine in chest injuries in which pleural penetration was evident or was a possibility was a roentgenologic survey of the chest and upper abdomen. In many cases, it could be determined clinically exactly what the damage was and what procedures were required for its correction. It was better, however, to take unnecessary pictures than to find out, in the midst of an operation, that they should have been secured. All films were developed and dried at once and taken to the operating room with the patient.

Posteroanterior and lateral films of the chest and upper abdomen were taken in the upright or semiupright position whenever the patient's condition permitted. Pictures in this position provided highly accurate information concerning the extent of the trauma and the organs involved and also revealed fluid levels. This routine was never followed in severely shocked patients. If lateral films were not satisfactory, as they rather frequently were not, oblique

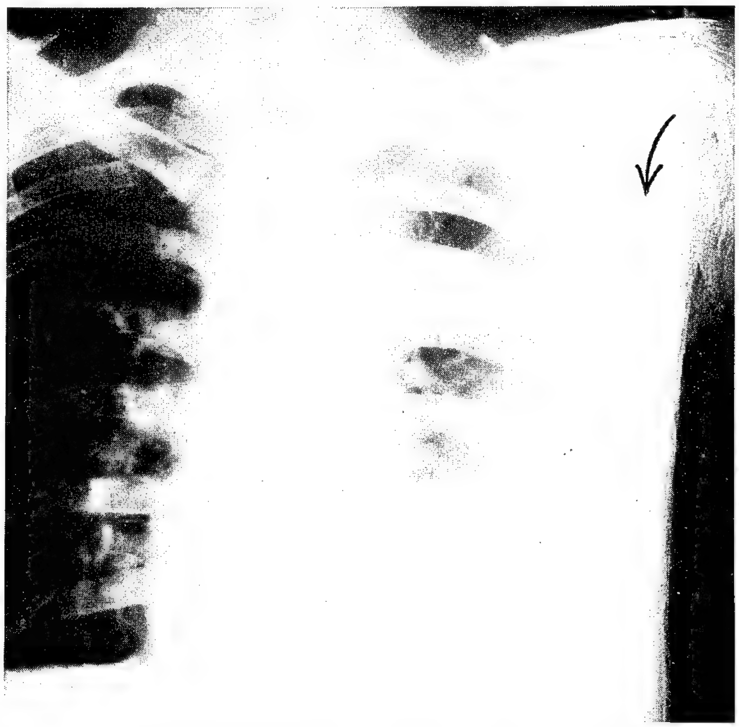

FIGURE 29.—Anteroposterior roentgenogram showing track of missile in left lung, with foreign body in left axilla.

films were made, or fluoroscopic examination was resorted to if the information was considered necessary. Neither method was employed routinely as part of the initial examination, though both were extremely useful later.

The usefulness of roentgenologic examinations in thoracoabdominal wounds has already been mentioned, as has their employment to demonstrate gastric dilatation which could not always be established by physical means.

Foreign bodies are discussed in detail elsewhere in this volume (vol. II, ch. VII), but a few words should be said about them at this point. If it was considered important to localize them at this echelon of medical care, additional films were made with the Potter-Bucky grid. The possibility that a foreign body was free in the pleural cavity always existed when roentgenograms showed the missile to be at a considerable distance from the point suggested by physical examination of the injury (fig. 29), especially if it lay low in the thorax. To substantiate the diagnosis, another film was taken with the patient in another position, to allow for a shift in the position of the object.

In cases in which there was no wound of exit on examination and roentgenograms revealed no evidence of a foreign body, there were two possible explanations:

1. The missile might have been of low velocity when it struck the chest and might have fallen back after causing the wound of entrance.

2. The missile might have had sufficient velocity to penetrate the abdomen or neck after passing through the chest. The number of these injuries was so large that in some hospitals it was routine to take films of both the abdomen and the thorax in all chest injuries. The policy was perhaps somewhat wasteful of films, but it saved time and eliminated the annoyance of having to take additional films later.

Reference

1. Tribby, William W.: Examination of One Thousand American Casualties Killed in Action in Italy. Report to Surgeon, Fifth U.S. Army, 1944, 6 vols. [Official record.]

CHAPTER IX

Resuscitation and Preoperative Preparation

Lyman A. Brewer III, M.D.

GENERAL CONSIDERATIONS

Adequate resuscitation of the wounded man before initial surgery was the policy that most clearly distinguished professional care in World War II from that of World War I. It was probably also the single factor that contributed most directly to the improved salvage rate. Essentially, it was based on the surgeon's appreciation of the entire status of the patient as well as of the nature and severity of his regional wound or wounds. For all battle casualties, regardless of the type of wound sustained, this led to the better management of shock. For the thoracic casualty, it led to consideration of his disturbed cardiorespiratory physiology not as an entity separate from shock but as a condition precipitating it or aggravating it.

About 2 percent of all casualties admitted to field hospitals were either dead on arrival or were in such poor condition that intensive resuscitation failed to improve them sufficiently to permit operation. Under no circumstances, however, was the condition of a patient who was admitted alive considered so hopeless that resuscitation was not attempted. This policy paid rich dividends. Many a casualty received without obtainable pulse or blood pressure responded to resuscitation and recovered after surgery.

Surgical Timing

In military practice, casualties with wounds of the abdomen were operated on as soon as their general condition permitted because continuing intraperitoneal hemorrhage or infection was always a serious possibility. Casualties with injuries confined to the thorax, on the other hand, ran their chief risks from altered cardiorespiratory mechanisms. Even if the timelag was prolonged, infection was not the serious possibility that it was in all abdominal injuries. It was imperative to correct the altered cardiorespiratory mechanism as promptly as possible; but it was seldom necessary to operate immediately in the absence of intra-abdominal injuries (thoracoabdominal or associated abdominal), traumatic amputations, or continuing hemorrhage within the chest or elsewhere.

It was the general opinion, founded on sound evidence and experience, that a casualty with a severe wound of the chest was in better condition for opera-

tion, and convalesced more rapidly afterward, if time were taken before operation for his blood pressure, pulse, and respiration to be restored to satisfactory levels. In such conditions as extensive pulmonary contusion from blast (vol. II, ch. I) or myocardial contusion (vol. II, ch. II), it was best to allow from 24 to 48 hours, or longer, to elapse before even minor surgery was undertaken. In blast injuries and contusions, in particular, it was a major, and often fatal, error to operate too promptly. Casualties who were held at the clearing station or field hospital for replacement therapy, oxygen, and other resuscitative measures, and who were held until full recovery from primary shock, were always received in better condition at an evacuation hospital than if they were rushed through without such care.

Resuscitation was not an end in itself, simply a means to an end. The end was corrective and restorative surgery. When the patient had reached an optimum stage of recovery, which in thoracic casualties was after cardiorespiratory stabilization, it was essential to operate without delay, for the status of a wounded man was never static, and deterioration was the rule if surgery was too long deferred.

The initial treatment of all thoracic casualties was always resuscitation, whether they required immediate operation in the field hospital or could be evacuated farther to the rear for surgery. No decision was made for or against emergency surgery until adequate resuscitative measures had been instituted (fig. 30). After they had been, emergency surgery in the field hospital that originally had seemed inevitable, often proved unnecessary. Even when the indication for emergency surgery was unquestionable, as it was when the injury was a large traumatic thoracotomy or an obvious thoracoabdominal wound, operation was never carried out without adequate resuscitation and preoperative preparation.

As far as the time element was concerned, it was important to shorten to the minimum the interval in which diminished oxygenation of the blood could produce cerebral damage. Once normal oxygenation of the tissues had been reestablished, the time interval from that point to surgery was not of major importance.

Personnel of Shock Ward

The medical officer who cared for casualties in the shock ward and prepared them for operation was a vital link in the successful management of chest injuries. Early in the war, there was an inclination to delegate the duties in this ward to anybody who happened not to have more pressing duties at the time. The fallacy of this policy was soon learned, and at a heavy price. It took experience and sound judgment to resuscitate a thoracic casualty intelligently and successfully. It took expert judgment to determine the optimum time for operation. A patient who was permitted to slip back into shock because advantage had not been taken of the optimum recovery to be expected was far

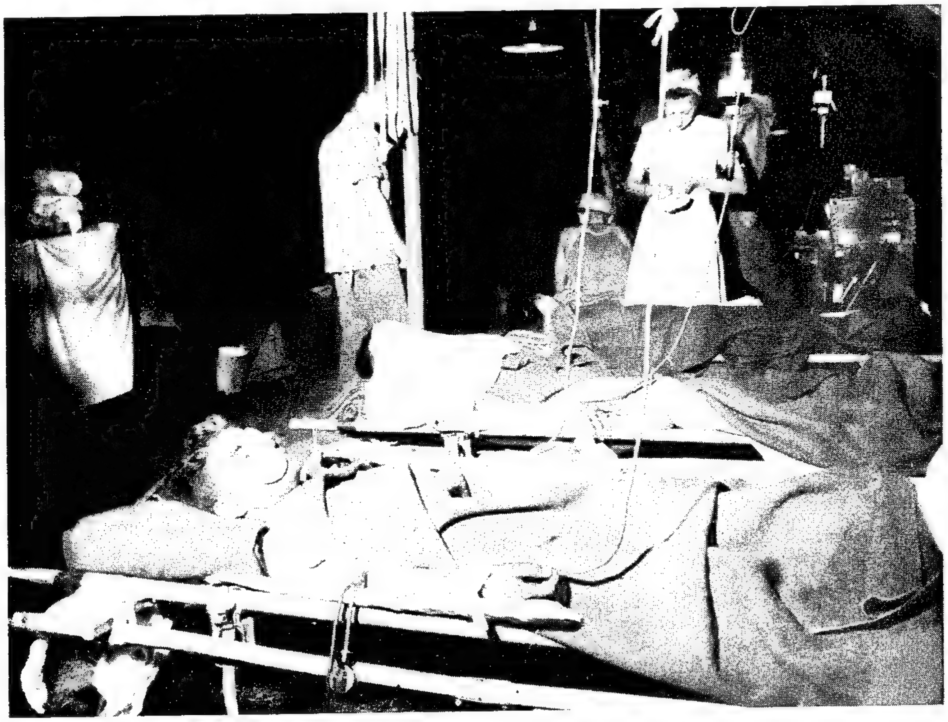

FIGURE 30.—Resuscitation of casualty with chest wound in shock ward of field hospital.

more difficult to resuscitate a second time and represented a far poorer surgical risk.

The evaluation of one special category of casualties could be quite misleading unless it was remembered that the combination of anoxia and excessive carbon dioxide could result in an elevation of the blood pressure, even when blood loss had occurred. If such a patient were taken to the operating room without any preparation at all, in the belief that he did not need it, surgery might prove fatal. Surgeons with an experience of combat-incurred chest injuries were aware of these cases, but an inexperienced medical officer was likely to feel a false sense of security about them. Such a patient might show a fall in blood pressure when the proper shock therapy was instituted.

The duties in a shock ward were best carried out by medical officers who were well grounded in the physiology of the cardiorespiratory system. As a rule, a well-trained internist was a better shock officer than a surgeon, however technically brilliant, who was poorly trained in physiology. Members of shock teams of auxiliary surgical groups proved ideal for this purpose. There was no single reliable guide to the status of shock in thoracic or other casualties, but the clinical impressions of an experienced medical officer were generally more useful than the measurement and numerical record of any body function.

Case Histories

The two case histories that follow illustrate the improvement that occurred in concepts and practices of resuscitation as the war progressed. The first patient was treated during the northern Tunisian campaign in the spring of 1943 and the second a year later, on the Cassino-Minturno sector, just before the drive on Rome.

Case 1.—This patient received a severe penetrating gunshot wound of the right posterior chest on 29 April 1943 at 0600 hours. He was admitted to a forward evacuation hospital, in severe shock, 10 hours later. Preoperative measures consisted of the administration of 500 cc. of plasma and 1,000 cc. of glucose solution by vein. Thoracotomy was performed at 1845 hours. The procedure consisted of removal of 1,000 cc. of blood from the right pleural cavity; segmental resection of the lower portion of the lower lobe of the right lung, which was badly lacerated; repair of a laceration of the diaphragm; crushing of the right phrenic nerve; and wound closure. Although a laceration of the loin was present, subcostal drainage was not provided. The patient was given 500 cc. of plasma and 1,000 cc. of glucose by vein. He did not react after operation and died at 0700 hours on 30 April, 25 hours after wounding.

Comment.—This case history illustrates a complete failure to apply the principles that should govern the initial management of all intrathoracic injuries. Although the patient was in severe shock, he was not adequately resuscitated before operation. He received no blood either before or during operation, though he had lost at least 1,000 cc. into the pleural cavity. The fluids he received must have resulted in dangerous hemodilution. He was submitted to major surgery while still in a state of shock. It is no wonder that he never reacted from it.

Case 2.—This patient was wounded at 0830 hours on 2 May 1944. He received multiple penetrating shell-fragment wounds, including a wound of the left chest and another of the left thigh, with a compound fracture of the left femur. When he was admitted to a platoon of a field hospital at 1200 hours, his blood pressure was 70/40 mm. Hg. He was moderately dyspneic and had a wet cough. The abdomen was diffusely tender and rigid in both upper quadrants.

As soon as the patient had received 500 cc. of low titer O blood, and 1,200 cc. of bright red blood had been aspirated from the left chest, his breathing became quieter, and his color improved. The aspirated blood was discarded, as the abdominal findings made its contamination likely. Intercostal nerve block on the left side was followed by prompt relief of pain in the chest wall, which was followed, in turn, by effective coughing and obvious clearing of the tracheobronchial tree.

After a second 500 cc. of blood had been given, the blood pressure was 105/60 mm. Hg, and the patient's general condition was greatly improved. Roentgenograms of the chest, abdomen, and left thigh in two planes showed a foreign body in the left upper abdominal quadrant and a complete fracture of the middle third of the shaft of the left femur.

Operation was performed at 1445 hours, after another transfusion of 500 cc. of low titer O blood. The occlusive dressing placed over the chest wound was not removed until an endotracheal tube was introduced. The sucking wound, 2.5 cm. in diameter, found in the fourth intercostal space in the midaxillary line was thoroughly debrided, and the pleuromuscular layers were closed.

A posterolateral thoracotomy incision was then made, with resection of the ninth rib. Approximately 500 cc. of blood was removed from the pleural cavity. A laceration of the left lower lobe was sutured with fine silk.

A 2-cm. laceration was found in the left hemidiaphragm and was extended. Exploration revealed a fractured spleen and a perforation of the splenic flexure with fecal spillage. The foreign body visualized by roentgenogram was found free in the peritoneal cavity. The spleen was removed. Spur colostomy was done after mobilization of the splenic flexure,

and the bowel was brought out through an incision in the left lower quadrant of the abdomen. After lavage of the peritoneal cavity with physiologic salt solution, 25,000 units of penicillin was instilled into it. The diaphragm was closed with silk. After copious lavage of the thoracic cavity, 25,000 units of penicillin was instilled into it. The lung was expanded and the chest wall closed.

The wound in the thigh was debrided, the fracture reduced, and a plaster spica applied.

As the final step in the procedure, the trachea and bronchi were thoroughly aspirated. During the operation, 1,500 cc. of blood was given, bringing the total amount administered to 3,000 cc.

At the end of the operation, the blood pressure was 110/75 mm. Hg and the patient was in excellent condition. Penicillin was given intramuscularly for 5 days after operation. Recovery was entirely uncomplicated.

Comment.—The management of this patient represents the mature application of modern resuscitative practices. The initial appraisal was careful and accurate. Resuscitation was prompt and expert. Cardiorespiratory physiology was brought back to almost normal. Whole blood was administered judiciously. In short, this was careful, expert preparation for major surgery, and the results were gratifying.

ROUTINE OF RESUSCITATION

The resuscitation of the soldier with a thoracic wound comprised five principal components:

1. The treatment of shock, which was usually hemorrhagic in origin, by adequate blood replacement.
2. Correction of the impaired cardiorespiratory physiology.
3. The relief of pain.
4. Restoration of the fluid balance.
5. Measures to prevent infection.

Although these procedures are discussed separately as a matter of convenience, in reality, they were carried out simultaneously and were all interrelated, just as the pathologic conditions which required correction were interrelated.

Treatment of Shock

The problems of resuscitative therapy in World War II were greatly simplified once there was general acceptance of the concept that the cause of the deterioration of the status of any seriously wounded man, regardless of the site of his wound or wounds, was a reduction in the circulating blood volume caused by loss of blood. These problems were still further simplified when the additional concept won general acceptance that, except for processes leading to dehydration, fluid loss from the circulation could be explained by local losses of fluid at the site of injury.

Concepts.—In thoracic casualties, the concept of shock had to be somewhat modified. The patient's condition was related, just as in wounds of any other area, to such factors as blood loss, tissue trauma, exposure, the timelag between wounding and medical care, and his status before he was injured. Although external blood loss might occur, bleeding was more often internal, into the pleural cavity, in which blood was not only lost to the circulating blood volume

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but in which it interfered mechanically with the cardiorespiratory function by preventing expansion of the lung. The principal causes of shock in thoracic casualties included, in addition to the loss of blood just described, painful wounds of the chest wall; sucking wounds; pneumothorax and tension pneumothorax; paradoxical respiration; cardiac tamponade; the accumulation of blood, mucus, or both in the tracheobronchial tree; and anoxia from any of these causes.

The most frequent cause of anoxia in thoracic injuries was the presence of blood, air, or both, in the pleural cavity, with a corresponding reduction of the functioning pulmonary tissue to a degree insufficient to maintain adequate oxygenation of the blood. Amounts of blood or air that would be of little consequence in the normal individual were of grave significance in the wounded man. They were superimposed upon the burden he was already bearing because of loss of blood, tissue trauma, and concomitant wounds. Combined dyspnea and anoxia in a thoracic casualty might result in a sharp decrease in vital capacity that might prove fatal unless vigorous resuscitative measures were instituted without delay. When anoxia was profound, there was also some fluid loss because of the general increase in capillary permeability associated with it.

The principal difference between a thoracic casualty and a casualty with any other type of injury was that the thoracic casualty, in addition to his actual chest wound and associated wounds, also had the all-important handicap of a disturbed cardiorespiratory physiology, and that this imbalance was likely to be the dominating factor in his condition. All attempts at resuscitation, including all measures to treat shock, would inevitably prove futile unless they included correction of the cardiorespiratory imbalance.

In thoracoabdominal wounds, another factor entered the picture. There might be spillage, sometimes massive, of fecal matter into the peritoneum or into the pleura through the transdiaphragmatic wounds or into both cavities. Shock arising from abdominal injuries and from other associated injuries compounded, and was itself compounded by, the shock caused by thoracic injuries.

The typical manifestations of shock were usually present in thoracic injuries, including a systolic blood pressure below 100 mm. Hg and frequently much lower; a rapid, frequently irregular pulse; rapid, shallow respirations; a lowered skin temperature; sweating; and pallor or cyanosis. In addition, the thoracic casualty was likely to be dyspneic. He also presented the extreme restlessness and apprehension characteristic of hypoxia and indicative of impending cerebral anoxia.

Posture.—Thoracic casualties who were hypotensive but who were not cyanotic or dyspneic were placed in the Trendelenburg position. In the absence of shock, the sitting position was ideal, since vital capacity was greater and coughing more effective when it was used. The semirecumbent position, however, was usually better tolerated by freshly wounded men, and it was therefore more generally used both for transportation and during resuscita-

tion. In this position, the patient lay on his back, with his head and chest slightly elevated, to permit the diaphragm to function more efficiently. A patient not in shock was sometimes more comfortable recumbent than semi-recumbent or sitting, and he was permitted to assume whatever position made respiration easier for him.

It was possible to perform an effective and complete thoracentesis without requiring the patient to change his position, no matter how he was lying or sitting.

Replacement therapy is considered later, under a separate heading (p. 253).

Correction of Cardiorespiratory Imbalance

Measures to correct the cardiorespiratory imbalance in thoracic injuries included oxygen therapy; the relief of pain; evacuation of the tracheobronchial tree; stabilization of the thoracic cage; thoracentesis for hemothorax, pneumothorax, or hemopneumothorax; management of sucking wounds; and management of tension pneumothorax. These measures are discussed separately, as a matter of convenience, and the order of presentation is no indication of their relative importance, which depended upon the special conditions present in each patient. As a matter of fact, the success of one of these measures was likely to depend upon the institution of one or more of the other measures. Oxygen therapy was urgently necessary in cyanosis, for instance, but it was not effective unless the airway was open.

Oxygen Therapy

The general appearance of the thoracic casualty furnished a useful guide to his need for certain therapeutic measures. The presence of cyanosis, which is an indication of comparatively advanced anoxia, was a warning that vigorous measures must be instituted, and instituted promptly, to correct the cardiorespiratory imbalance. Other signs of cerebral anoxia, such as unconsciousness or maniacal manifestations, made the correction of the decreased blood oxygenation even more urgent.

The efficacy of oxygen in the management of shock was a frequent source of discussion during the war, but there was never any argument over the indication for its use in all thoracic injuries associated with any degree of respiratory difficulty. All casualties diverted to a field hospital were admitted to the shock ward (fig. 30) immediately upon their arrival, regardless of the nature and severity of their wounds, and here the shock officer practically always instituted oxygen therapy for those with thoracic injuries. Specifically, it was used promptly and freely for any patient who was restless or dyspneic or whose pulse remained elevated (over 110). It was even better to administer it before cyanosis and restlessness developed. A patient could readily pass from a state of simple restlessness into a manic state that was frequently the immediate precursor of death.

Once normal oxygenation of the tissues had been restored, the timelag to surgery became of less importance. The essential consideration was to shorten to a minimum the period in which a diminution of the blood oxygen supply could produce cerebral damage.

The most efficient way to administer oxygen was by the Boothby-Lovelace-Bulbulian mask, but it was also perfectly satisfactory to administer it by an intranasal catheter. The minimum rate of flow was 7 liters per minute. Administration was continued until cyanosis, dyspnea, and tachycardia were relieved.

Relief of Pain

As pointed out elsewhere (p. 231), pain was an almost constant accompaniment of any wound of the chest. The clue to its correct management was the realization of the fact that painful stimuli originate in the thoracic wall and not in the lung itself. The relief of pain had a vital bearing on hastening recovery from shock. Until it had been accomplished, the patient was unwilling to breathe deeply or cough, because of the discomfort which followed both acts, and fluid substances therefore accumulated in the tracheobronchial tree, which led to wet lung (vol. II, ch. V).

Administration of morphine.—When a casualty was seen at the clearing station or field hospital, he had usually had an injection of morphine, given by the company aidman when he reached him on the battlefield. The standard Army syrette contained gr. ½, and this was usually the size of the dose the casualty had received. It would have been better if the standard syrette had contained only gr. ¼. The smaller dose has practically the same pain-abolishing power as the large dose, without its depressant effects, but, in spite of much discussion on the subject, gr. ½ remained the standard dose throughout the war.[1]

A dose of this size was not harmful to many patients, but it was distinctly harmful to casualties who were already in severe shock and suffering from impending or actual anoxia. It was therefore the policy, after management of chest injuries had been standardized, not to give morphine in clearing stations or field hospitals to patients suffering from hypoxia, particularly if restlessness indicated that cerebral anoxia was impending.

Even a small dose of morphine dulls the sensorium, decreases respiratory efficacy and increases cerebral anoxia, all undesirable effects in casualties with chest injuries. Another serious effect was that the patient as he became less sensitive, also became less aware of the accumulation of secretions in the tracheobronchial tree and made no effort to remove them.

The use of morphine also presented other problems. Some wounded men had had two, or even three, injections before they reached the field hospital.

[1] As a matter of fact, although the desirability of a smaller dose of morphine in the standard syrettes was called to the attention of the Medical Research and Development Board in June 1943, on the basis of the work of Dr. Henry K. Beecher at the Massachusetts General Hospital, official action was not taken until August 1954. At that time, the amount of morphine in the syrette was reduced to gr. ¼.

Casualties were frequently heavy, and the medical officer in the battalion aid station, the collecting station, or the clearing station often had no time to appraise the individual patient's symptoms and to determine whether his complaints were really caused by pain or were of some other origin. Cerebral anoxia was frequently accompanied by restlessness that at times seemed maniacal. In this sort of rushed atmosphere, particularly before the risks of oversedation were realized, it was easy to consider that the patient was writhing in pain and natural to give him an injection of morphine. The patient who deteriorated under this policy was the one who was already in rather marked shock, with hypotension and poor peripheral circulation. The first morphine administered, therefore, was not picked up by the lagging circulation, particularly if the environment was chilly or cold. As a result, more was given, and it too was not picked up. When, however, the patient was brought into a warm environment and measures to correct his shock were instituted, the circulation improved, and all of the morphine in the subcutaneous tissues was picked up. The result was a cumulative effect which might result in morphine poisoning.

In view of all these considerations, there was seldom any indication for the administration of additional morphine to the thoracic casualty in a clearing station or field hospital. If it was indicated, the intravenous route was preferred because the effects are more predictable and can be immediately assessed.

A small group of thoracic casualties, who had received morphine, presented a clinical picture for which no explanation was ever adduced. They were observed more often in the late fall and winter months, after they had lain out in the cold and wet for many hours, than when the weather was more moderate. They presented the typical picture of morphine overdosage; that is, they had pinpoint pupils, their respiratory rate was slow, and they were difficult to arouse. Yet their records only occasionally showed that they had had more than a single injection of morphine, which sometimes was gr. ¼ and not gr. ½. If the records could be accepted, these patients were not suffering from morphine poisoning, which had been the original assumption.

It is of course possible that in some of these cases the records were inaccurate. On the other hand, the same clinical picture was seen too often to accept possible recording error as the universal explanation. This condition was a well-proved clinical entity. No definite proof for the theory was ever produced, but it was postulated that these patients presented another manifestation of relative anoxia. Almost invariably, they were severely wounded; they had frequently suffered from exposure; and they were cyanotic unless they were given oxygen.

Strapping.—In civilian practice, adhesive strapping is rather widely used for the immobilization of fractured ribs and to relieve the pain caused by them. This method was used to some extent early in World War II, but it frequently accomplished neither of the desired purposes, and the patients complained of the discomfort caused by the adhesive.

The chief contraindication to this method was that it is unphysiologic. Many patients with fractured ribs showed varying degrees of wet lung (vol. II,

ch. V), with increased bronchial secretions, blood, transudates, and sometimes intrapleural bleeding. When the lungs were compressed and expansion of the chest restricted by adhesive strapping, the secretions became more difficult to raise. Therefore, as the war progressed, it became the policy to reserve this method for the stabilization of a flail chest associated with paradoxical motion (p. 248).

Nerve block.—Instead of morphine, which depressed respirations, or strapping, which mechanically limited respirations, the policy was to block the painful impulses near their origin, which proved to be far more effective. This was accomplished by procaine hydrochloride injection of the intercostal nerves supplying the wounded area.

Regional block was employed in preference to local infiltration at the injured site because the probable contamination of all wounds made injections close to the injured area undesirable. Regional block was a simple, efficacious procedure which could be accomplished in 5 or 10 minutes (vol. II, ch. V) and which produced lasting results. In the usual case, it was not necessary to block the sympathetic chain, nor was there any evidence that this technique produced any better results than those obtained by simpler intercostal injection. Any sympathetic block probably also anesthetized the contiguous intercostal nerve roots. Furthermore, injection of the intercostal nerves usually anesthetized the sympathetic nerve fibers accompanying the intercostal vessels.

Unless one had observed the results of nerve block, it was hard to conceive the immediate relief of pain and the improvement in the casualty's condition that usually followed this procedure. A patient who had been unable to cough, or who would not attempt to cough because of pain, now coughed without difficulty. Clearing the tracheobronchial tree of blood and other secretions by vigorous coughing rapidly changed a hypotensive, cyanotic, dyspneic casualty to one with deep, unhurried respirations; good color; and a prompt return of blood pressure to more normal levels. A single injection usually gave relief from pain for at least 24 hours, and frequently only a single injection was necessary. The relief of pain for periods of 24 hours or more, far longer than the pharmocologic effect of procaine, was a surprise to frontline surgeons who observed this phenomenon for the first time. The exact mechanism was not known. The most plausible explanation was that the blocking of the sympathetic nerve fibers of the intercostal vessels, mentioned previously, improved the blood supply to the chest wall and pleura sufficiently to prevent arteriospasm and ischemic pain.

Transportation of casualties with chest injuries was so frequently facilitated following nerve block that this method was sometimes employed in forward installations on this indication alone.

Evacuation of the Tracheobronchial Tree

Concept of wet lung.—The management of the condition that came to be known as wet lung and that is described in detail elsewhere (vol. II, ch. V) was

so important a part of the resuscitative routine that certain details concerning it must be repeated here.

In any kind of chest injury, including fractured ribs, blast injuries, and both parietal and intrathoracic wounds, there were two pathologic factors, (1) abnormal fluids in the tracheobronchial tree, and (2) the patient's inability to expel them adequately. The pulmonary tissue, following chest trauma, reacted by producing more than the normal amount of interstitial and intra-alveolar fluid. Increased mucous secretions and intrapulmonary and intrabronchial hemorrhage further compounded the difficulty.

Inadequate evacuation of tracheobronchial fluid and blood was observed in the majority of casualties with serious chest wounds, sometimes within a few hours after injury, sometimes not until 6 or 7 days had elapsed. The accumulation of fluid in the chest interfered with adequate blood oxygenation because it impaired the absorptive functions of the alveoli. It greatly increased the surgical risk if operation was performed without its recognition or before it was corrected. It was a serious complication in the postoperative period, and, before its importance was realized, it was responsible for a considerable number of deaths.

Clinical picture.—The most common symptoms and signs of wet lung were oral wheezing; rhonchi heard constantly over one or both sides of the chest; and a frequent, painful, ineffectual, wet cough. Only small amounts of sputum were raised, and the bubbling character of the respirations persisted after the secretions had been coughed up. Tenacious mucus and blood constituted the bulk of the fluid, but an occasional purulent exudate was present, signifying a preexistent bronchitis. Wet lung was an entirely different entity from massive collapse of the lung (atelectasis), which was the result of obstruction of the main bronchus. This latter complication was very infrequent in the Mediterranean theater, probably because of the attention paid to the diagnosis and management of wet lung.

Management.—The aim of treatment in wet lung was to improve bronchopulmonary drainage. Sedative cough mixtures were contraindicated. Morphine was withheld unless incontrovertible indications for its use were present; then it was given in very small amounts and always intravenously. If the secretions were frothy and fine rales were heard, some surgeons used atropine (gr. 1/100), but no evidence existed that it was really useful in clearing the tracheobronchial tree, and there was some evidence that it was harmful.

Two adjunct measures were helpful, (1) the administration of oxygen (vol. II, ch. V), and (2) the relief of thoracic pain by nerve block (vol. II, ch. V), after which the patient was willing to cough. Vigorous coughing was the simplest and most effective method of clearing the chest of obstructing secretions. If he was alert enough to understand the situation, the necessity was explained to the patient in detail. Personnel in the shock tent were instructed to help him cough effectively by holding the chest or supporting the abdomen if the act caused pain or discomfort in either location.

Suction was necessary for patients who could not clear the trachea and bronchi by the simple methods described. The introduction of a catheter, as demonstrated by Haight (*1*) in 1938, was then carried out without delay. The irritation caused by its introduction and presence stimulated all but unconscious and almost moribund patients to cough and thus rid themselves of much more secretion than could be removed by aspiration of the catheter alone. Catheter aspiration was a particularly useful measure in comatose or semicomatose patients or patients who had been heavily sedated, none of whom could cough voluntarily and effectively.

Usually only one or two aspirations were necessary, but the procedure could be repeated as often as necessary. When aspiration had to be repeated frequently, it was best to introduce a Magill intratracheal tube and aspirate the trachea through it by inserting the catheter at regular intervals. When a catheter was left indwelling, oxygen was administered through it between aspirations.

If catheter aspiration was not promptly effective, bronchoscopy (vol. II, ch. V) was resorted to without delay and was repeated as necessary. Experience showed that it could be performed twice a day without any ill effects, although one bronchoscopic aspiration was all that was usually needed. Catheter aspiration was most often effected after bronchoscopy.

Occasionally, continued bleeding prevented successful clearance of the tracheobronchial tree. In such cases, further delay was considered unwarranted. The patient was removed at once to the operating tent, for rapid induction of anesthesia with endotracheal intubation, which permitted more complete tracheobronchial suction. It was the general experience that the necessary surgery could be proceeded with, without further delay, as soon as the airway had been completely cleared.

When the retained transudates, secretions, and blood in the lung were controlled by this plan, tracheotomy was seldom necessary as an emergency measure. In some instances, however, either the patient was not in condition to withstand a thoracotomy, or a thoracotomy was not the answer to his problem. In these circumstances, tracheotomy was performed.

The continued extravasation of fluid transudates into the alveoli and from trauma of the bronchi resulted in a type of pulmonary edema which clinically was similar to that seen in other conditions. Mechanical aspiration of fluid was ineffectual in correcting it, and excess fluid continued to be formed in the alveoli. The intermittent administration of positive pressure oxygen (vol. II, ch. V) was found to be highly effectual in decreasing fluid production and ultimately drying up the lungs. This mode of therapy was sometimes lifesaving in preparing casualties for surgery, though those in irreversible shock were likely to prove refractory to it.

Stabilization of the Thoracic Cage

Flail chest, caused by multiple rib fractures, is discussed in more detail elsewhere. It was always serious, and, if the paradoxically moving seg-

ment of the chest wall was large, it could endanger life. Localized flail chest could be controlled by regional nerve block, sometimes stabilized by a pressure dressing held in place by an elastic binder. Lying with the affected side down was sometimes useful, as was the use of small sandbags. When the affected area was larger and paradoxical motion was excessive, mechanical means of stabilization had to be employed. Occasionally it was necessary to insert a sterile towel clip, under aseptic precautions, around the central rib of the affected segment. This was followed by the use of light traction, obtained by a cord attached to a weight, usually of about 3 to 5 pounds, suspended over a pulley attached to an overhead frame. Stabilization was sometimes accomplished in 4 or 5 days, but it might be necessary to maintain traction for from 7 to 14 days.

In severe flail chest, with extreme paradoxical respiration, management of the wet lung syndrome might be extremely difficult. In these circumstances, strapping of the chest or the use of a firm binder was occasionally necessary to prevent ballooning out of the chest wall. The method was never officially forbidden, but, with very occasional exceptions, its use was avoided, since strapping simply increased the anoxia by limiting the motion of the chest wall. In addition, it served as an actual handicap to the propulsive mechanism of the act of coughing. In fact, it was frequently observed that patients who had been strapped improved considerably as soon as the strapping was removed.

Management of Sucking Wounds

Any injury to the chest wall which produced an open wound into the pleural cavity caused profound disturbances in the intrathoracic physiology, chiefly because of the exchange of air in the pleural cavity and the outside atmosphere. As a result, the normally negative intrapleural pressure was replaced by atmospheric pressure. The type and size of the wound were generally correlated with the effects of these alterations on the cardiorespiratory physiology.

In every so-called sucking wound, there was usually a decrease in the vital capacity immediately after the injury was sustained. The decrease was progressive and, if it was not interrupted, led to mediastinal flutter; interference with the right side of the heart; and increasing anoxia resulting from pendulum respiration.

A patient with a properly treated sucking wound—as all wounds of the chest eventually came to be managed—arrived at the field hospital with an occluding dressing over it. The preliminary inspection was to make certain that it had not been disarranged during evacuation. If it had been, it was at once replaced.

Before an ineffectual dressing was replaced, it was sometimes useful to evacuate a portion of the air or blood that had collected in the pleural cavity, particularly if the injury were of the valvular type. This was easily accomplished by placing the patient in such a position that the wound was roughly dependent. Its edges were held open during forced expiration and coughing

and were approximated during inspiration. Several hundred cubic centimeters of air and fluid could often be rapidly removed by this simple method.

When this procedure was completed, another dressing was applied, twice as large as the wound and thickly impregnated with petrolatum. It was applied across the wound and covered with a large gauze dressing held firmly in place with adhesive strips. This dressing was left in situ until the patient was on the operating table. It should be stressed again, however, that the original dressings were not disturbed if they were occluding the wound satisfactorily and the pleural opening was airtight when they were first inspected.

If there was a pulmonary, bronchial, or tracheal tear of any moment, then a tension pneumothorax, with collapse of the lung, might develop after the integrity of the pleural cavity had been reestablished by an occluding petrolatum-impregnated gauze pack. In these circumstances, a needle, or preferably a catheter, as used in tension pneumothorax, was placed in the second interspace parasternally to provide for the escape of air. This was an essential precaution if leakage of air into the pleural cavity continued.

Experience early in the war showed that any wound that was not of the sucking or blowing type while the casualty lay in one position, might readily become one with a change of position of the body or even of the arms. It was, therefore, the rule that the chest wound should be closed with the type of dressing just described in all patients who were to be transported farther to the rear without surgery in the field hospital.

The original practice of dusting the wound with sulfanilamide powder was generally, though not universally, discontinued in the summer of 1944.

Sucking wounds are discussed in greater detail under that heading (vol. II, ch. I).

Management of Tension Pneumothorax

Air entered the pleural cavity in all wounds of the chest wall. If the amount that entered was inconsequential, or if it gave rise to no clinical signs and symptoms, the intrapleural air was termed a pneumothorax. If the pneumothorax was of sufficient volume to cause respiratory embarrassment, the contained air was termed a tension or pressure pneumothorax. In other words, the difference between a pneumothorax and a tension pneumothorax was not in kind but in degree.

In spite of its infrequency, tension pneumothorax was a constant threat in combat-incurred chest wounds, and preventive measures had to be employed in every case in which it was a possibility.

The clinical picture included extreme dyspnea, which was the most prominent feature, eventual cyanosis, fullness of the neck veins, hyperresonance of the involved hemithorax with absence of breath sounds, and a shift of the heart and mediastinum to the opposite side.

Management.—When tension pneumothorax was present, immediate treatment was required, though thoracotomy was not indicated unless there was reason to suspect a wound of the trachea or of one of the large bronchi.

Oxygen was given by nasal catheter for cyanosis, persisting rapid pulse, and restlessness caused by anoxia. As an emergency measure, a large-bore needle (16–18) was inserted into an upper (preferably the second) anterior intercostal space, strapped in place, and connected to a water-seal bottle. If tension still persisted after several hours, a catheter (16–18 F.) was substituted for the needle and was connected to a water-seal bottle (fig. 31).

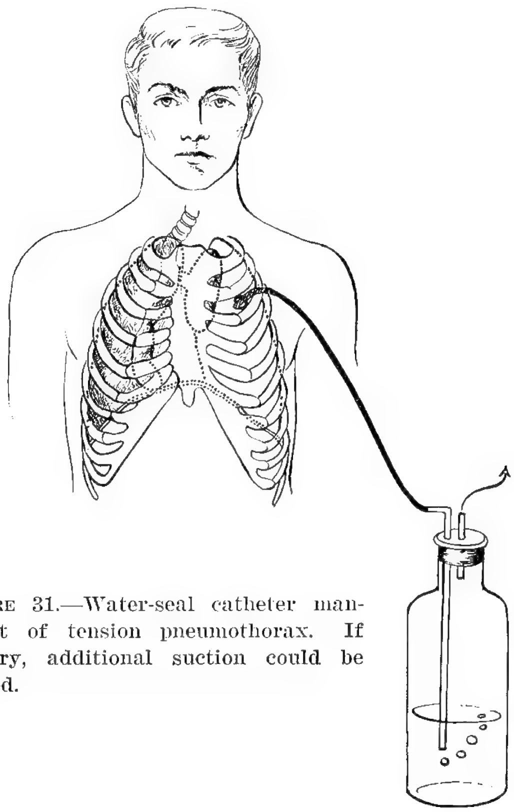

FIGURE 31.—Water-seal catheter management of tension pneumothorax. If necessary, additional suction could be produced.

The response to the measures described was usually prompt and striking. Dyspnea and cyanosis disappeared. As decompression was accomplished, palpation demonstrated that the trachea had resumed its normal midline position and was no longer displaced to the opposite side. In the occasional case in which air continued to leak into the pleural cavity in spite of these measures, thoracotomy was undertaken, but usually only after a period of observation of from 18 to 24 hours. In occasional instances, a large laceration of the trachea or bronchus required earlier operation.

If a patient with a tension pneumothorax had to be transported before decompression was accomplished, because of the tactical situation or for other reasons, a needle still in situ was replaced by a catheter, and a flutter valve replaced the water-seal bottle. A condom or the split finger of a rubber

glove permitted the escape of fluid and air (fig. 32). Water-seal drainage during evacuation was neither convenient nor safe.

Tension pneumothorax is discussed in greater detail under that heading (vol. II, ch. IV).

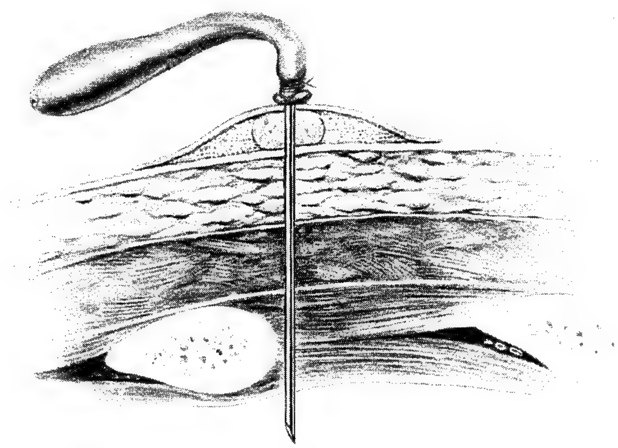

FIGURE 32.—Management of tension pneumothorax. Needle introduced through second interspace anteriorly, through cork, with finger cot flutter valve in situ.

THORACENTESIS

Since a large hemothorax or hemopneumothorax could reduce the vital capacity to dangerously low levels, thoracentesis was an important part of resuscitation of the thoracic casualty. It was performed whenever any appreciable amount of blood or air was present, appreciable amount being defined as an amount which could be detected at the dome of the diaphragm on physical examination. With the intrapleural cavity emptied, the lung could reexpand, and an immediate improvement occurred in the vital capacity. The military experience did not bear out the anxiety felt in some quarters before the war that thoracentesis immediately after wounding might cause a resumption of bleeding from the injured pulmonary parenchyma (vol. II, ch. VI).

The amount of blood obtained gave some indication of the severity of the intrathoracic damage and aided in an appraisal of the structures injured and in the decision concerning the best method of treatment. It was also a sound guide to the amount to be replaced by transfusion. If the injury had occurred less than 12 hours earlier, and the blood was considered to be uncontaminated, it was occasionally aspirated directly into a sterile Baxter donor bottle and returned to the patient as an autotransfusion (p. 256). This practice was contraindicated on even the suspicion of a thoracoabdominal injury.

Sterile aspiration sets were eventually standard equipment in all shock tents. A 17-gage needle was used, preferably with a short, beveled point

rather than a sharp point, to avoid damaging the lung. The needle was connected with a vacuum bottle or with a syringe with a 3-way valve to prevent air from entering the chest while the blood was being aspirated. An assistant clamped the tubing when the syringe was removed to be emptied. The vacuum bottle was placed lower than the patient, usually on the floor. If standard equipment was not available, a short piece of rubber tubing, with appropriate adapters, could be used.

If the needle was introduced low in the axilla, it was possible to remove almost all of the fluid from the chest without making any change in the position of the patient. The site of preference for its insertion was the sixth or seventh interspace in the posterior axillary line or the second anterior interspace in the midclavicular line.

In an uncomplicated hemothorax, no serious attempt was made to empty the pleural cavity completely as part of the resuscitative regimen. At this time, the purpose of the procedure was simply to expand the lung and relieve pressure on the mediastinum. No rule could be laid down concerning the amount of blood to be removed at any single aspiration, but it was seldom necessary to discontinue the procedure because of the amount per se. From 1,200 to 1,500 cc. could usually be removed with impunity. The most reliable guide was the status of the patient and the appearance of symptoms due to too rapid attempts to expand the lung. If he complained of a tight feeling and pain in the chest, dyspnea, or dizziness, aspiration was temporarily discontinued and resumed later.

Hemothorax is discussed in greater detail under that heading (vol. II, ch. VI).

REPLACEMENT THERAPY

Special Considerations in Thoracic Wounds

Replacement therapy was an essential component of resuscitation in chest wounds, but its use was hedged about by a number of qualifications and precautions which did not have to be considered in other types of wounds.

As in all other injuries, the clinical estimation of the need for fluid replacement was based upon the nature of the wound; the known loss of blood; the condition of the patient, including the blood pressure and the pulse and respiratory rates; and the surgery which would be necessary. Facilities for hemoglobin and red blood cell determinations were always available, and later in the war, the copper sulfate method for determination of the hematocrit and plasma protein levels was introduced and proved very useful in regulating fluid replacement.

In chest injuries, however, these observation could not be accepted without qualification. Other circumstances had to be taken into consideration:

1. Deficient oxygenation, whether caused by an obstructed airway, pulmonary compression or contusion, or a cardiac wound, could, in itself, without an excessive loss of blood, produce the typical clinical picture of shock with a

low or unrecordable blood pressure and a rapid, feeble, irregular pulse. Faced with this picture, the inexperienced medical officer was apt to institute rapid blood replacement, a procedure that could be fatal to a casualty with an already unbalanced cardiorespiratory system.

2. Restitution of cardiorespiratory physiology reduced the amount of fluid replacement necessary in thoracic wounds, but this improvement did not mean that replacement therapy could be arbitrarily reduced in amount or omitted entirely. At least a quarter of all thoracic injuries were thoracoabdominal, and half or more were associated with wounds in other parts of the body. Thus shock that was not of thoracic origin or not wholly of thoracic origin was a compelling entity in a large number of thoracic wounds. In such cases, it was augmented and complicated by disturbances in cardiorespiratory physiology, but even after they were corrected, it persisted and was an indication for replacement therapy.

With the correction of reversible pleuropulmonary changes, the resultant increase in the pulmonary capillary area permitted more vigorous replacement therapy, with a reduced degree of risk. It was still necessary, however, to follow a precise resuscitative regimen in which the risk of pulmonary edema was nicely balanced against the need for whole blood. Sound judgment was required to insure that the casualty received the blood that he needed but at the same time did not receive so much that his precarious, recently restored, cardiorespiratory balance was endangered.

Large transfusions, rapidly administered, were not well tolerated by casualties with damaged lungs and secondary cardiac disturbances:

1. They were particularly poorly tolerated when the injuries were the result of blast. Flooding of these patients with large amounts of blood or plasma could produce acute pulmonary edema, which might be an important factor in the fatal outcome.

2. Casualties with partial or complete pneumothorax, who were suffering from hypoxia caused by reduction in the vital capacity from such mechanical causes as hemothorax and pneumothorax, might also develop pulmonary edema by sudden overloading of the decreased pulmonary vascular tree.

3. The vascular bed in chest injuries was already reduced by partial collapse of the lung, and it could be further reduced by the extensive hematoma of the pulmonary parenchyma present in some cases. The rapid introduction of blood in such cases, with no time allowed for compensation, produced a further, abrupt reduction in the vascular bed.

There was never an indication for rapid transfusion in thoracic casualties unless continued bleeding from a large vessel was occurring or there was knowledge of serious blood loss earlier. As has been pointed out several times, the surgical time factor, after correction of the cardiorespiratory imbalance, was not a matter of extreme importance in chest wounds.

Generally speaking, unless the casualty was obviously bled out, it was best not to start any sort of intravenous therapy on a patient who was coughing and whose chest showed gross rhonchi. After the airway had been cleared by

aspiration, thoracentesis performed, and pain relieved, so that normal respirations were possible, hypoxia promptly improved. Then the pulmonary vascular bed could better tolerate intravenous fluids in the necessary amounts. It was a mistake to administer blood, especially in quantity, until failure to respond to these measures made it clear that blood loss was playing a major role in the casualty's state of shock. The level of the blood pressure did not furnish the absolute guidance in chest injuries that it did in other wounds, since cardiorespiratory imbalance might be more at fault than actual blood loss.

Plasma Transfusion

Plasma was sometimes administered to thoracic casualties before they reached the clearing station, and in many instances it was lifesaving, particularly in Tunisia, where ambulance hauls were often long and trying. In a report to the Surgeon, II Corps, after this campaign, Maj. Francis M. Findlay, MC, and Capt. (later Maj.) Marion E. Black, MC, noted that it was impractical to give plasma in U.S. Army ambulances, a serious defect in view of these circumstances. Some surgeons believed that if a patient needed plasma, he should not be transported until it had been administered. Another suggested that when long ambulance hauls were necessary, a halfway station should be established, in charge of a medical officer whose function it would be to check the status of each casualty and remove from transit those in need of plasma. The different circumstances in the campaigns in Sicily and Italy made these expedients unnecessary.

A tendency to give too much plasma in the aid and collecting stations was sometimes noted, particularly early in the war, before the limitations of this agent were understood. The administration of excessive amounts placed an extra burden on the already impaired circulatory system of thoracic casualties and sometimes resulted in decompensation, as well as in the development of the wet lung syndrome. The overgenerous use of plasma in installations ahead of the field hospital also made it difficult to give the necessary amounts of blood when the field hospital was reached.

Techniques of Transfusion

Unless the patient was obviously exsanguinated, the most practical plan was to introduce 500 cc. of blood at a moderately rapid rate and then slow the rate of administration. How much more blood was necessary could then be checked by laboratory determinations, though an experienced shock officer or chest surgeon usually could settle the matter without this aid. If 1,500 or 2,000 cc. had to be given, the transfusion was allowed to run over a period of hours.

Since most casualties with chest injuries had to be placed on the operating table on one side or the other, much time was saved, as well as much stress for the patient, if transfusion was started in one of the veins of the leg. This also

simplified the procedure when a patient with multiple wounds had to be turned to expose them. The needle could usually be introduced at the ankle, without a cannula. If a cannula had to be used the site of preference was the saphenous vein, just above the internal malleolus.

A needle in the antecubital fossa was likely to become dislodged as the patient was moved. Then the anesthesiologist had to turn his attention from the anesthesia to replacing the needle and restarting the blood. The use of a leg vein was practical from another standpoint, that rapid administration of blood might become necessary in the course of the operation.

Patients with chest wounds associated with multiple wounds of the extremities frequently needed prolonged intravenous replacement therapy and had no available avenues of administration. Then other techniques were used, such as sternal puncture or administration of the blood through the external jugular vein or the corpus cavernosum of the penis.

Autotransfusion.—Early in the war, before the blood bank was established at Naples, it was a frequent practice, as already noted, to use for autotransfusion the blood which had been aspirated from the pleural cavity. This practice was not followed in thoracoabdominal wounds, even if only the diaphragm had been injured.

While autotransfusion was frequently employed after the blood had been in the chest up to 12 hours, most surgeons believed that from 4 to 6 hours was a much safer limit. Severe reactions (chills, fever, and toxic manifestations) could follow the use of blood aspirated from the chest, partly because of the hemolysis of the red blood cells it contained and partly because of the presence in it of pleural transudates high in protein; blood is an irritant to the pleura, and its presence gives rise to a rapidly developing serous effusion with a high protein content. Autotransfusion was seldom employed late in the war.

Blood secured from the chest was collected into a transfusion bottle or flask, through several thicknesses of fine-mesh gauze. If the autotransfusion was not to be performed immediately, which was the best plan, sodium citrate was added to the blood. If the blood was used at once, it was administered through the recipient tubing set with the stainless steel mesh filter incorporated in the package containing the flask.

Intravenous Crystalloid Solutions

Intravenous crystalloid solutions were practically never employed in chest injuries. There was no indication for their use except in the occasional case in which dehydration was so extreme that it required immediate correction.

Banked Blood

During the African and Sicilian campaigns, large quantities of fresh whole blood were made available from what amounted to a living blood bank of service troops. The men were classified as to blood type, and each donor on the list

was replaced by another as soon as he had given blood. Donors were secured from the same source during the early fighting in Italy. In February 1944, a blood bank was set up in Naples, and thereafter adequate supplies of fresh whole blood were available from this source. Provision for blood was part of the preparation of the Seventh U.S. Army for the invasion of southern France in August 1944.

Blood flown from the United States was never sent to the Mediterranean theater. The problem therefore did not arise, as it did in the European and Pacific theaters, concerning the use of blood diluted with Alsever's fluid in chest casualties. Fresh blood was desirable for thoracic casualties because of the deterioration of red blood cells in the excessive fluid in blood preserved by this method. This was a particularly important consideration when multiple transfusions were likely to be necessary.

EMPTYING OF THE STOMACH

Correct preoperative preparation included emptying of the stomach before anesthesia, to avoid the risk of aspiration of gastric contents, which could lead to serious pulmonary consequences (p. 292). This measure was desirable in all wounded men and urgently necessary if food had been taken after wounding or as recently as 2 hours or less before wounding. As a matter of fact, the length of time since the patient had taken food was not a sound criterion of the amount of material likely to be in the stomach. A large residue was often present many hours after ingestion of food, possibly as the result of pylorospasm or of lessened gastric motility because of the nervous tension of combat.

An additional reason for inserting a Levin tube before operation in all chest injuries was that in some cases, gastric dilatation was great enough to enhance the respiratory difficulties already present.

RESUSCITATION IN THORACOABDOMINAL WOUNDS

In thoracoabdominal wounds, speed of resuscitation was essential because speed of surgery was essential, just as in any abdominal wound. In these injuries there was always the possibility, if not the probability, that contamination of the peritoneum, as well as of the pleural cavity, was occurring and that continued hemorrhage might threaten life. There was therefore no reason for temporizing and delay after cardiorespiratory imbalance had been corrected, replacement therapy begun, and the diagnosis established with reasonable certainty. Even when the response to adequate resuscitative measures was not entirely satisfactory, delay in the shock tent did not, ideally, exceed 1 to 3 hours at the maximum. In all thoracoabdominal wounds, the operation was itself an essential part of the regimen of resuscitation.

Thoracoabdominal wounds are discussed in greater detail under that heading (vol. II, ch. III).

RESPONSE TO RESUSCITATION

Criteria of adequate resuscitation included:

1. Spontaneous cessation of hemorrhage or its control.
2. Establishment of a patent airway.
3. Stabilization of the chest wall and restoration of its integrity.
4. Effective cough.
5. Control of shock.
6. Establishment of an adequate cardiorespiratory balance.
7. Clearance of blood and air from the pleural space.
8. Reexpansion of the lung.

After adequate resuscitation, the patient's status was reevaluated in the light of these criteria. Not all of them were met in all cases, but, as a rule, enough of them had been to make surgery safe. It was not necessary that completely normal conditions be reestablished before it was undertaken. When the cardiorespiratory balance had been restored by correction of hemothorax, pneumothorax, and stabilization of the chest wall, the systolic blood pressure was likely to have reached 80 mm. Hg and to be tending upward, and surgery could safely be undertaken.

If resuscitation had been adequate but the patient's status was still poor, certain other possibilities had to be borne in mind in the patient whose shock was obviously not irreversible:

1. Leakage of air in large amounts from the trachea or bronchus.

2. Soiling of the pleura with esophageal or reflux gastric contents.

3. Continuing hemorrhage from an intercostal or mammary vessel, which was not frequent (vol. II, ch. IV).

4. Cardiac tamponade, which was not common in military surgery (vol. II, ch. II).

5. Intraperitoneal or intrapleural contamination from spillage of the contents of a hollow viscus. Gross contamination of the left pleural cavity by large bowel contents produced as profound shock as was seen during the course of the war. In such injuries, a response to resuscitative measures could be expected only after the cause of the shock-producing mechanism had been eliminated.

6. Intraperitoneal hemorrhage. Early surgical intervention was necessary when, for instance, the spleen lay shattered in the left pleural cavity or the right lobe of the liver continued to bleed. If the site of the wound of entry in the chest, the location of retained metallic fragments, and the lack of response to shock therapy pointed to continuing hemorrhage, with or without other intra-abdominal injuries, then the surgeon had to weigh the possibilities and proceed with surgery in spite of the patient's continued shock. If fecal contamination of the peritoneum or pleura had also occurred, the response to resuscitation was slower than if only hemorrhage was a factor. If contamination had been serious and of long duration and if there had also been a massive loss of blood, then the patient might not react at all.

Any of these conditions served as a sound indication for thoracotomy or thoracolaparotomy. A satisfactory response to resuscitation could not be expected while they remained uncorrected.

Priority of surgery.—The combined effect of multiple injuries also seriously influenced the response to resuscitation. Furthermore, the frequency with which other wounds of varying severity complicated intrathoracic wounds often made the decision as to regional priority of management extremely important. There was general unanimity on this point: When wounds of the thorax presented indications for early thoracotomy, this operation was always done before other surgery. The single exception, which was not usual, was severe intra-abdominal hemorrhage. Total equilibration of the cardiorespiratory mechanism enabled combined procedures of surprising magnitude to be done safely.

PSYCHOLOGIC CONSIDERATIONS

Often during the stress of combat, when a hospital was filled to overflowing with battle casualties, there was a tendency, quite understandable under the circumstances, to forget the casualty as an individual and consider him only in terms of his injury. This was a particularly serious error in the management of patients with chest injuries. They were often apprehensive, and the knowledge that they might be harboring foreign bodies in the chest often caused them a great deal of concern. Ideal management, therefore, required that they receive the maximum reassurance possible. Relief of pain and improvement in respiration were probably the two factors that did most to improve the mental attitude of the severely wounded. Morale was high in the forward hospitals of the Mediterranean theater because of the skill and esprit de corps of the surgical staffs and because it was common knowledge among the fighting men in the forward echelons that if they lived to reach a forward hospital, they were almost certain to recover.

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CHAPTER X

Anesthesia

Ernest A. Doud, M.D.

GENERAL CONSIDERATIONS

The excellent anesthesia provided for casualties with wounds of the chest in World War II was brought about by two developments between the two World Wars. The first was the development of intratracheal positive pressure absorption anesthesia. The second was improvement in the knowledge of cardiorespiratory physiology (*1*).

Thoracic surgeons and anesthesiologists with adequate equipment were dispersed from the forward areas of the combat zone back through the chain of evacuation. This policy greatly reduced the fatalities from chest wounds as well as their morbidity. It permitted the prompt and competent care of nontransportable casualties by providing for surgery, when it was necessary, as near the frontline as it was practical to provide hospital facilities.

The need for qualified anesthesiologists for the management of thoracic injuries was recognized early in the war. It was also recognized that they must take the responsibility for more than the administration of anesthesia. In addition to relieving the surgeon of all concern for anesthesia, they assumed the responsibility for shock therapy during operation, and, when it was practical, before operation. They also coped with the ever-present problems of pulmonary secretions and accumulations of intratracheal blood by repeated catheter aspiration during operation, and, if necessary, by bronchoscopy immediately afterward.

The duties of the anesthesiologist and his relation to the surgeon are excellently stated in the final report of the 2d Auxiliary Surgical Group on forward surgery:

> * * * the anesthetist carries a large part of the responsibility in treating severely wounded men. The more competent the anesthetist the less the burden on the surgeon. With a well-qualified anesthetist at the head of the table the surgeon can give his undivided attention to the operative procedure itself.

It was generally agreed that such an anesthetist could "support an inexperienced surgeon better than a brilliant surgeon [could] maintain an inexpert anesthetist."

EQUIPMENT

Satisfactory anesthesia depended upon adequate equipment. There were many deficiencies early in the war, both in North Africa and in Sicily. Even in the Sicilian campaign, some thoracic surgical teams of the 2d Auxiliary Surgical Group did not have anesthesia machines. Inductions had to be carried out with open drop ether or ethyl chloride, or with Pentothal sodium (thiopental sodium), with oxygen administered by face mask or nasopharyngeal catheter. In many instances, the entire intrathoracic procedure was carried out with intravenous Pentothal sodium (p. 84).

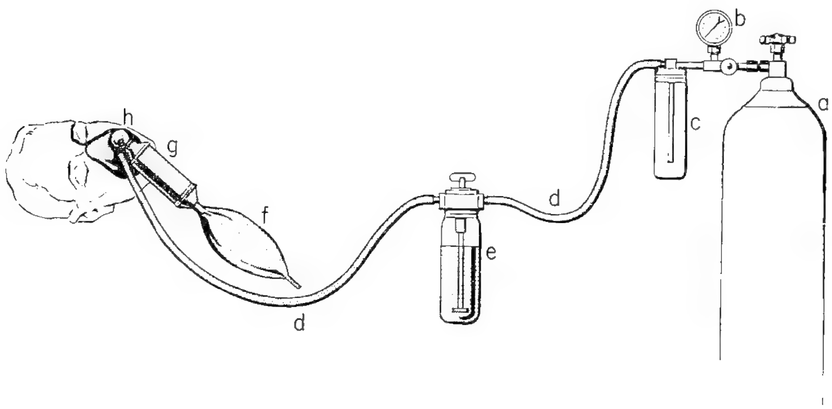

Figure 33.—Improvised anesthesia apparatus used in Sicily by the 2d Auxiliary Surgical Group. The oxygen cylinder (a), oxygen flow regulator (b), and humidifier (c) were standard hospital equipment. Other items improvised included the connection tubing (d), ether vaporizer (e), breathing bag (f), soda-lime canister (g), and face mask (h).

There were numerous improvisations (fig. 33) in many of which ordnance and engineering units assisted. Several types of ether vaporizers were devised. Positive pressure was obtained by occluding the escape valves of masks through which oxygen was administered and manually compressing the attached small breathing bag. Neither nitrous oxide nor soda lime was available at this time. Large volumes of oxygen were used to dilute the carbon dioxide.

After November 1943, these difficulties no longer existed. Several types of excellent anesthesia machines were distributed, and there were ample supplies of oxygen, nitrous oxide, ether, Pentothal sodium, and soda lime. The equipment and supplies were made available not only to hospitals but to the mobile surgical teams. Thereafter, anesthesia left nothing to be desired, for by this time the anesthesiologists had learned the necessary lessons of wartime anesthesia by their experiences in the early campaigns.

PREOPERATIVE PREPARATION

The excellent results obtained in all types of combat injuries in World War II could be attributed in large part to the excellent preparation of the

casualties for both anesthesia and surgery. Originally, until thoracic surgical teams were assigned to field hospitals, surgeons were responsible for triage; resuscitation and preoperative preparation, including procuring blood for transfusion from neighboring service troops; and determination of the optimum time for operation. When field hospitals were set up adjacent to clearing stations, which was first done in the campaign in Sicily, thoracic surgical teams were assigned to them, and anesthesiologists took over the major part of the responsibility for resuscitation. They employed, as necessary, replacement therapy, nasotracheal catheter suction, tracheal intubation, paravertebral block, and whatever measures might be necessary (p. 241). They also assisted the surgeon in determining the optimum time for operation. This was preferably after resuscitation was completed. If, however, the condition of the casualty continued to deteriorate in spite of adequate therapy, whatever surgery was indicated was performed at once.

Preoperative medication.—Preoperative medication was almost always administered intravenously in the operating tent, to make certain of satisfactory absorption, so that whatever drug was used would have the optimum effects at the desired time.

All patients, except those in deep shock, were given atropine sulfate (gr. 1/150 to 1/100). If sedation was thought necessary, morphine tartrate was administered (gr. 1/8 to 1/4). It was always administered cautiously, for it was not infrequently found that casualties with chest wounds had already received too much. Until this was realized, acute morphine intoxication was not uncommon. When the circulation improved in response to resuscitative measures, the morphine previously administered to casualties in shock, who had been exposed to cold and wet weather, was rapidly absorbed. In such circumstances, an additional dose of morphine could be dangerous (p. 244).

For this reason, intercostal or paravertebral nerve blocks with procaine hydrochloride (Novocain) were frequently used in preoperative preparation in preference to morphine. If the injuries involved only the chest wall, patients who had been treated by nerve block during resuscitation could sometimes be operated on with the addition of procaine infiltration analgesia. This method, however, had a limited use, because the multiplicity of wounds restricted the employment of both local and regional anesthesia.

TECHNIQUE

Induction.—Anesthesia was easily induced in some patients with ether and oxygen or with open drop ether. In other cases, nitrous oxygen and oxygen were used, with the gradual addition of ether. When it was advisable to eliminate possible excitement during induction, the most satisfactory combination of drugs was the intravenous use of Pentothal sodium (table 13) in 2.5- to 5-percent solution and the topical use of cocaine in 4- to 10-percent solution, with preliminary oxygenation.

TABLE 13.—*Distribution of anesthesia by type, and by type of hospital, Seventh U.S. Army, 1 November 1944–30 April 1945*

Type of anesthesia	Evacuation hospitals		Field hospitals	
	Cases	Percent	Cases	Percent
Intravenous (Penthothal sodium)	22, 363	53. 1	71	2. 8
Inhalation [1]	9, 762	23. 2	2, 148	86. 2
Combined intravenous and inhalation	3, 849	9. 1	56	2. 2
Field blocks	4, 904	11. 6	45	1. 8
Regional (miscellaneous)	558	1. 3	117	4. 7
Spinal	383	. 9	11	. 5
Sympathetic block	319	. 8	44	1. 8
Total	42, 138	100. 0	2, 492	100. 0

[1] Endotracheal anesthesia was used 3,042 times in evacuation hospitals and 1,782 times in field hospitals, this being 31.2 percent and 83.0 percent, respectively, of the inhalation anesthetics given in those installations.

Anesthetic agents.—Ether was the principal anesthetic agent used in most chest wounds. It was seldom used alone but was highly satisfactory when combined with nitrous oxide and oxygen, or with Pentothal sodium, or simply with oxygen.

Pentothal sodium with oxygen was used as the principal anesthetic agent only when lack of equipment and supplies required it, which was seldom the situation after the campaign in Sicily.

This agent had many advantages: It did not irritate the bronchial mucosa. Respiratory movements were reduced to a minimum, and the surgeon therefore did not suffer from interference by them. Controlled respiration was easily effected with it. When it was used with ether, only small amounts of that agent were required. On the other hand, Pentothal sodium gave rise to occasional laryngospasm, and the postoperative respiratory depression that it caused was likely to be prolonged. The chief reason for restricting its use to selected patients and for using it only when other types of anesthesia were not possible was its very small margin of safety. It was not a proper agent for general use.

Positioning.—Unless there were contraindications, such as head injuries, the modified Trendelenburg position was used during operation, for two reasons. The first was that it reduced the possibility of air embolism. The second was that it was helpful in improving the condition of the casualty, particularly the shocked casualty, during anesthesia.

Tracheal intubation.—The trachea was intubated routinely, to facilitate positive pressure for pulmonary control and expansion without causing gastric dilatation. Another purpose was to stabilize the mediastinum during intrathoracic surgery. A soft rubber catheter was passed through the tube, and frequent tracheobronchial aspirations were carried out to protect the contralateral lung from gravitated material.

The tube used was the largest which would pass through the glottis without difficulty. Some anesthesiologists preferred a tube with an inflatable cuff, in the belief that the cuff prevented fluid accumulations in the trachea from escaping around the tube into the pharynx. Others preferred to pack the pharynx with moistened gauze, in the belief that the packing prevented the tube from acting as a wick to permit regurgitated material to be drawn into the trachea. Still others preferred to place a mask over the tracheal tube, thus producing a seal for attaining positive pressure.

Usually when the ether was used, and always when Pentothal sodium was used, the respiratory exchange was increased by rhythmic manual compression of the breathing bag throughout the operation.

Opinion was divided as to whether intermittent positive pressure anesthesia or the apneic technique of controlled respiration was the preferred method for maintaining anesthesia for surgery with open pneumothorax. However it was attained, 2–3 mm. Hg pressure prevented mediastinal shift, and 10–12 mm. Hg pressure was used to expand the lung for short periods every 20–30 minutes during operation, as well as when the wound was being closed.

Curare.—Curare was used intravenously by one surgical team during the Italian campaign to obtain abdominal relaxation and to facilitate tracheal intubation (*2*). The drug, which was not on the approved list, was supplied to the anesthesiologist of this team by the manufacturer and used by special permission on a trial basis. Curare proved extremely useful in obtaining abdominal relaxation, but it never came into widespread use, one reason being that the supply was scanty.

ADJUNCT THERAPY DURING OPERATION

As accurate as possible an estimate of the blood lost was made as the operation progressed, and the estimated loss was replaced as it occurred, to prevent the casualties, whose balance was always delicate, from slipping into shock. The physical status of many patients improved during operation because of (1) the increased efficiency of respiratory exchange following aspiration of the trachea and administration of oxygen in high concentration, (2) the effects of the Trendelenburg position, and (3) intravenous replacement therapy, usually in the form of whole blood transfusions.

The anesthesiologist was kept fully employed during operation with the administration of the anesthetic; maintaining respirations; keeping the tracheobronchial tree free of fluid; constant evaluation of the patient's condition; and the administration of intravenous fluids, sometimes under pressure, to increase the rate of flow if the blood loss was particularly heavy.

BRONCHOSCOPY

Bronchoscopy was not routinely used at the end of thoracic operations, chiefly because most anesthesiologists believed that increasing the depth of anesthesia at this time would have deleterious effects. It was, however, used

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whenever necessary to make certain that respiratory passages were clear of blood and mucus, as well as to determine the patency of the bronchi if too great resistance was offered to pulmonary expansion. It always had to be borne in mind that the uninjured lung had been in a dependent position during surgery. It was frequently necessary to clear the left stem bronchus, which was likely to present special difficulties.

Bronchoscopy was sometimes necessary, before operation, to clear accumulations in the tracheobronchial tree after failure of attempts at blind nasotracheal suction. Circumstances sometimes made it wiser to delay suction until the tracheal tube was inserted after rapid induction of anesthesia. Oxygen was administered with a little positive pressure after each brief period of suctioning. When the respiratory passages had been satisfactorily cleared, anesthesia was continued and the operation proceeded with.

The chief risk of bronchoscopy, the vagovagal reflex, could be eliminated by the administration of atropine before the procedure was undertaken. The risk of omitting it is evident in the following case history:

Case 1.—This casualty, a 23-year-old soldier, was injured by a high explosive shell fragment on 26 May 1944 at 0730 hours. He was admitted to a field hospital 4 hours after injury, after having received morphine gr. ½ and 3 units of plasma. The blood pressure was 84/50 mm. Hg and the pulse 120.

The wound of entry was over the eleventh rib, in the left posterior axillary line, and was 4 cm. in diameter. The wound of exit was in the anterior axillary line and was 6 cm. in diameter. Omentum had herniated through both wounds. The left chest was silent, and haziness was evident throughout it by roentgenologic examination. The abdomen was tender and rigid.

The patient received another unit of plasma and 1,400 cc. of blood before operation. Preoperative medication consisted of morphine gr. ⅙ and scopolamine gr. 1/100. When operation was begun, the blood pressure was 110/70 mm. Hg and the pulse 110.

Operation was begun at 1430 hours. The wounds of entry and exit were debrided, and a large hematoma of the muscles was excised. Segments of the eighth, ninth, and tenth ribs were found shattered; their rough edges were smoothed.

An intercostal incision was then made through the eighth interspace. The pleural cavity contained 1,000 cc. of blood. Part of the stomach, the transverse colon, and the spleen, covered by omentum, had herniated into the left chest through a huge rent in the anterolateral portion of the diaphragm at its point of attachment to the chest wall. The spleen was widely macerated, but the pedicle had not been injured, so bleeding was not profuse. Splenectomy was performed and the damaged omentum resected. The tail of the pancreas was found lacerated and was repaired with interrupted cotton sutures. A 3-cm. laceration of the serosa over the greater curvature of the diaphragm was closed with some difficulty by two-layer imbricating cotton sutures. The phrenic nerve was paralyzed. The chest was irrigated with 2,000 cc. of physiologic salt solution. The wound was dusted with 5 gm. of sulfanilamide powder and closed in layers. Mobilization of muscles was necessary to secure adequate closure. A heavy dressing of gauze and wide adhesive was applied to stabilize the chest. Replacement therapy during the operation, which took 2 hours and 15 minutes, consisted of 500 cc. of blood.

The bronchoscope was then introduced, without difficulty. Although the patient had previously been in excellent condition, he became cyanotic and pulseless just as the procedure was being terminated. The immediate insertion of an intratracheal tube and the use of artificial respiration were without effect. The heart was not heard any time after bronchoscopy was performed.

An immediate post mortem examination showed the heart to be flabby and dilated, but otherwise, except for the traumatic damage, no abnormalities were found.

Comment.—It was concluded that the patient died of a vagovagal reflex, which undoubtedly could have been prevented by atropinization before the bronchoscope was introduced.

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CHAPTER XI

Initial Wound Surgery

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GENERAL CONSIDERATIONS

Although it necessitates a certain amount of repetition, it seems worthwhile to begin the discussion of the forward surgery of thoracic casualties with a restatement of the principles which governed their management in the division and army area. As pointed out in detail earlier (p. 199), the indications for thoracotomy in forward hospitals remained in a state of flux from the landings in North Africa in November 1942 until they were clarified under the direction of Col. Edward D. Churchill, MC, Consultant in Surgery to the Surgeon, Mediterranean Theater of Operations, U.S. Army, at a meeting of chest surgeons in Marcianise, Italy, in March 1944. Experience satisfactorily arbitrated most of the differences of opinion that still existed, and the consulting surgeon, by discussion as well as directive, effectually settled the remaining issues. With the clarification of indications for thoracotomy, many fewer such operations were performed, and results were correspondingly better.

Establishment of Policies

One of the chief arguments of the surgeons who believed thoracotomy was frequently required in field and evacuation hospitals was that it was necessary to prevent infection. Thoracic casualties, like all other casualties, sometimes did die from infection, but infection was not the usual cause of the deaths that occurred soon after wounding. Early deaths were practically always due to disturbances of cardiorespiratory physiology.

In thoracic casualties, prevention of infection, however important it was ultimately, was thus a secondary consideration immediately after wounding. At this time, the chief attention was directed to the cardiorespiratory balance, which, in most wounds of the thorax without abdominal involvement (thoracoabdominal wounds are discussed separately (vol. II, ch. III)), could be restored to normal or close to normal by resuscitative measures alone. Respiration is dependent upon lung expansion, and lung expansion is dependent upon an intact thoracic cage. The object of the management of thoracic casualties in forward hospitals was therefore the restoration of a functioning lung that was fully expanded against a restored thoracic wall.

Indications and contraindications for forward thoracotomy.—While the general policy early in the Tunisian campaign and for some months afterward was to perform thoracotomy in forward hospitals on very liberal indications, experience rapidly accumulated to show that overzealous surgical interference soon after wounding resulted in an increased morbidity and mortality. The mortality rate was lowest, and complications were fewest, when forward surgeons performed major intrathoracic procedures only on specific indications. These results were what might have been expected. Thoracotomy, even when it was absolutely necessary, put an added burden on an already damaged cardiorespiratory system. When he performed it unnecessarily, the forward surgeon might unwittingly be administering the coup de grâce to the casualty.

At the meeting in Marcianise, in March 1944, it was decided that theater policy thereafter should be to limit primary thoracotomy, whether by extension of the wound or by a separate incision at a site of election, to the following indications:

1. Continuing intrapleural hemorrhage not controlled by hemostasis in the course of debridement of the chest wall. This situation was uncommon.
2. Anatomic or clinical evidence of penetration of the diaphragm, which was common.
3. Large intrapleural foreign bodies or other debris readily accessible by simple extension of the wound. These were common.
4. Wounds of large bronchi or of the intrathoracic portion of the trachea, which were uncommon.
5. Passage of a missile through, or its lodgment in, the mediastinum, with reason to suspect visceral damage, particularly injury to the esophagus. These injuries were not frequent.

The following conditions were not, in themselves, to be regarded as indications for thoracotomy either by extension of the wound or by a separate incision:

1. Foreign bodies, whether metallic objects or fragments of bone, whether they were in the lung or the pleural space.
2. Hemothorax. Evacuation of blood from the pleural cavity by suction at the time of debridement of the chest wall wound was not considered a thoracotomy.
3. Laceration or contusion of the lung in the absence of definite evidence of continuing hemorrhage or leakage of air.

It was eventually found practical to base the management of a wound of the chest on its size. Arbitrarily, a traumatic thoracotomy came to be defined as a wound of the chest wall that, when debrided, resulted in a pleural defect 6 cm. or greater in one diameter or one that resulted in the destruction of three or more ribs and all intervening structures. Actually, this definition covered most sucking wounds: Since these wounds had to be sutured to make the pleural cavity airtight, a wide debridement of the chest wall muscles was necessary in

all of them. This sort of defect was most often caused by a fragment from a high explosive shell, though it was sometimes caused by a bullet that struck the thoracic cage tangentially or that emerged from the chest wall in such an erratic manner as to produce a disproportionately large defect. The size of the foreign body was not necessarily proportional to the size of the defect that it caused.

From the surgeon's standpoint, the important consideration was that a traumatic thoracotomy was not of his making. It was the result of wounding, and the wound was of such a size as to permit any indicated intrapleural manipulations. The intrathoracic damage in many instances might not, of itself, have required forward surgery. The surgeon simply took advantage of the exposure provided by the wound to perform whatever intrathoracic surgery might be necessary later.

Components of initial wound surgery.—Initial wound surgery, on the basis of these indications and contraindications, was therefore to consist of:

1. Debridement of the chest wall, without inspection of, or operation on, intrathoracic structures. This restriction did not preclude aspiration of blood or air from the pleural cavity by means of thoracentesis or by the insertion of a catheter through the pleural defect, irrigation of the chest cavity, and intrathoracic instillation of penicillin solution. Closure of the pleural defect by approximation of the muscle and fascial planes was considered part of debridement. Closure of the pleura per se was often not possible; the pleura is so delicate and so friable that it tears when suture is attempted.

2. Traumatic thoracotomy (thoracotomy through the wound), with debridement of the chest wall and inspection of, or operation on, intrathoracic structures as indicated. If necessary, the traumatic wound was extended to achieve this purpose.

3. Formal thoracotomy, with the incision at a site of election separate from the wound as indicated.

Modifications of Policy

The policy of limiting surgery in field hospitals to nontransportable thoracic casualties (p. 91) was, of course, flexible. It varied with local conditions, including such considerations as speed of evacuation, the terrain over which evacuation was to be accomplished, the location of the evacuation hospital in relation to the field hospital, and the casualty load. Two other considerations were important, (1) the availability of anesthetic facilities and personnel and (2) the relative competence of the personnel of the two installations. Even though it meant an increase in the timelag, the patient's interests were usually better served if additional time were taken to transport him to a hospital staffed and equipped for thoracic surgery.

Similarly, the surgeon doing chest surgery in a field or evacuation hospital was expected to depart from the strict policies just outlined when there was valid reason to do so. He could, for instance, go far toward relieving the load on base hospitals if he removed accessible foreign bodies at debridement, though

the presence of a foreign body was not, in itself, an indication for thoracotomy in a forward hospital. If the surgeon who performed the initial wound surgery aspirated the blood in the pleural cavity, a large hemothorax, which might later lead to infection or require decortication, would probably be avoided. The forward surgeon, by the exercise of sound judgment and by taking advantage of opportunities that presented themselves, could, while adhering to the general principles laid down for his guidance, prevent increased morbidity, including infectious complications, and make secondary surgery unnecessary.

DEBRIDEMENT

Debridement of all wounds of the external chest wall was mandatory, though in the absence of definite indications for more radical forward surgery, it could usually be postponed until an evacuation hospital was reached. No wound was too small to require debridement, and failure to perform it adequately could result in extremely serious infections. The operation included excision of all devitalized tissue, washing out of all dirt and foreign material with sterile saline solution, and packing of the wound with sterile fine-mesh gauze or roller bandage.

Chest surgeons who cared for casualties in base hospitals stated that it was practically always necessary to perform delayed debridement on wounds that had not been debrided originally because they were thought to be too small to need it or because they had been caused by high-velocity missiles and were regarded as sterile. In such wounds, a subcutaneous area of tissue destruction was invariably found, out of all proportion to the wound of entry, and direct extension of the infection to the pleural space could also be demonstrated. If the wound had been properly debrided, the fine-mesh gauze (ordinary bandage) could be removed in from 7 to 10 days at the base hospital and secondary closure of the wound performed.

Positioning

When only debridement of the chest wall was to be done, the location of the wound influenced the decision as to positioning on the operating table. Patients verging on shock were kept in the Trendelenburg position unless head wounds contraindicated it. The same position was considered desirable whenever lung tissue had been damaged or was to be cut across, on the theoretical assumption that the risk of air embolism would thus be decreased.

If a posterolateral traumatic thoracotomy or formal thoracotomy was necessary, the patient was placed on the intact side, with the chest at a right angle to the table (fig. 34). A small rolled blanket or bath towel was placed under the axilla to prevent pressure on the axillary nerves. Restricting pads were avoided, as was pressure beneath the costal margin on the underside of the chest, next to the table, so that there would be no compression of the underdiaphragm. Freedom of movement of the underdiaphragm was important during a thoracotomy that collapsed the uppermost lung. The thigh and leg nearer the table

were flexed, to help stabilize the patient. The other thigh and leg were extended, and the foot was fixed to the end of the table. Rolled blankets or sandbags were used to support the anterior chest. Satisfactory positioning on the table was completed by passing a broad adhesive strapping from the lower edge of the table across the hips, between the crest of the ilium and the greater trochanter of the femur, and thence down to be fixed to the opposite side of the table.

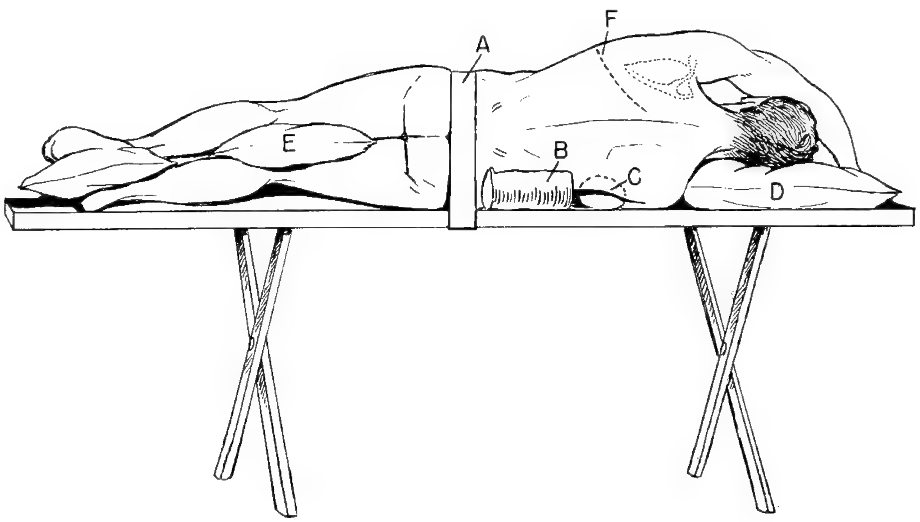

FIGURE 34.—Position on operating table for posterolateral thoracotomy. A. Adhesive strap over hips to hold patient to table. B. Fixation of position by sandbags, used in field and evacuation hospitals when regular operating tables were not available. C. Rolled towel or small pillow in underlying axilla, to prevent injury to brachial plexus. D. Pillow under head. E. Pillow between legs. F. Site of posterolateral incision.

Steps of the Operation

The cardinal principle of debridement was that it be thorough. Failure to perform adequate debridement introduced the risk of pleural infection and could lead to empyema. The wound was often grossly contaminated by dirt and bits of clothing. Large masses of muscle were often so badly contused as to be nonviable. Bone fragments were numerous, and accessible foreign bodies were frequent.

A nice balance between radical and conservative surgery was always attempted. The wound track was excised down to the pleural opening, but only devitalized tissue was excised. Only loose fragments of bone were removed; as much as possible of the ribs, periosteum, and intercostal structures was preserved. Too radical removal of the bony structures might be followed after operation by instability of the chest wall and paradoxical motion. Rib fractures that had not penetrated the pleura were not disturbed except to smooth

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FIGURE 35.—Debridement of chest wound in field hospital.

the sharp, rough edges of the stumps with a rib-cutter. If only the inner or the outer table of a fractured rib was displaced, the intact half was left in situ, on the ground that half a rib furnished more support to the chest wall than no rib at all. Periosteum was saved at all costs; it was used to bridge defects, for the bone regenerating from it prevented paradoxical movement of the chest wall. Only accessible foreign bodies were removed. All damaged intercostal bundles were ligated anteriorly and posteriorly, whether or not free bleeding was occurring. Care was taken not to include intact intercostal nerves in the ligated bundles. Intercostal structures were not resected unless they were actually damaged, since their excision would have enlarged the defect.

A simple debridement of the chest wall (fig. 35) included removal of damaged muscle tissue; removal of accessible foreign bodies and debris; and removal of fragments of the scapula, clavicle, superficial portions of the sternum, and superficial rib fragments. The pleura was not disturbed by any of these procedures. Once the debridement had become extensive enough to include the undersurface of the ribs and the pleura, then a traumatic thoracotomy had been performed, and the resulting open pneumothorax required positive pressure anesthesia and introduced other problems and risks. It was unwise to undertake a debridement of any considerable extent without facilities for intratracheal anesthesia.

When debridement was performed according to the technique and limitations just described, it was found that no other forward surgery was necessary

in three-quarters or more of all chest injuries. Whatever other surgery was indicated could be safely performed later at a fixed hospital in the base.

Aspiration of the pleural cavity.—All but the most insignificant wounds of the chest caused a pleural defect large enough to admit a No. 15 or No. 18 French catheter. In most cases, however, diligent aspiration of the chest with a needle was just as effective in the removal of retained blood as was the use of a catheter, and, being simpler, was preferable. When a catheter was used, a suction machine was attached to it. If aspiration was adequate at operation, postoperative aspiration was seldom necessary for any length of time and was frequently not necessary at all.

In some cases in which the blood had clotted and could not be satisfactorily removed by thoracentesis, a catheter was inserted through the pleural defect and worked back and forth to break up the clots. When as much material as possible had been removed by this method, the pleural space was irrigated with from 1,000 to 2,000 cc. of physiologic salt solution, which was then aspirated through the catheter with the aid of the suction machine. A hole cut in the catheter near the proximal end permitted digital control of the degree of suction applied.

Closure of the Wound

Whether initial wound surgery was limited to debridement or included some intrathoracic procedure, careful closure of the chest wall was equally important. It was essential that the muscle layer be closed, for two reasons:

1. The muscles furnish strength and support to the chest wall, which the skin and pleura do not.

2. It was imperative that any leakage of air into the pleural cavity be prevented. If the leak was small, a tension pneumothorax might result. If it was large, a sucking wound might develop.

While closure of the pleura was not always feasible, it was desirable whenever possible; an intact and well-healed pleura furnished an efficient barrier against the spread of infection from muscle layers to the pleural cavity. The risk of empyema was always reduced when the muscle layer of the chest wall was firmly closed and when the pleura, if possible, was also closed.

There were several techniques of closure:

1. Under ideal circumstances, it was a simple matter to reapproximate the muscle layers in tiers with interrupted sutures of either fine cotton or silk for all layers. Catgut was used for the pleura. The skin wound and subcutaneous tissues were closed later in a base hospital or chest center, by delayed primary wound closure.

2. Under less ideal, and more usual, circumstances, considerable skill and ingenuity might be required to effect adequate closure without tension. It was essential that tension be avoided. It was almost invariably followed by infection, and even a minor infection could rapidly result in an infected blowing wound and total empyema.

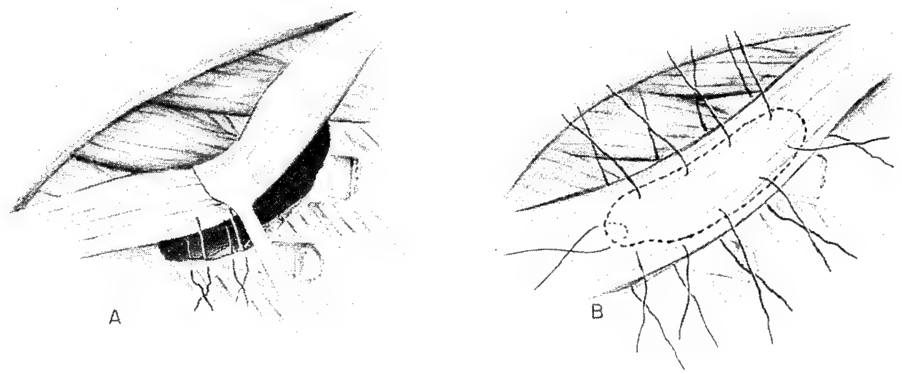

FIGURE 36.—Techniques of closure of sucking wound. A. Mobilization of latissimus dorsi flap to cover defect of sucking wound. B. Latissimus dorsi flap tightly sutured to edges of defect of sucking wound.

3. Whenever possible, closure was effected with intercostal structures, but extracostal muscle sometimes had to be employed (fig. 36). If the desired results could be accomplished by undermining and mobilizing adjacent muscle, closure offered no great difficulties, but the available muscle structures were usually insufficient for this purpose. In these circumstances, muscle flaps had to be swung into place. Ample muscle was available posteriorly, but near the spine, muscles are not so plentiful on the thoracic cage, and it was frequently necessary to use a flap of the erector spinalis to close the defect (fig. 37). Anteriorly, only the pectoral muscles are available (figs. 38 and 39), and if for any reason they could not be employed, closure had to be effected with subcutaneous fascia and skin.

In planning a muscle flap, it was always necessary to calculate a length 50 percent greater than the distance from its base to the far side of the defect. The additional length was necessary to compensate for the retraction that inevitably occurred when the flap was cut and that would have introduced the dangerous factor of tension, which had to be avoided. The deep fascia of the flap was used for closure of the first layer of the wound. Closure of the other layers was effected by imbrication of the split edge of the flap and of the muscles adjacent to the defect.

4. Pericostal sutures as the sole method of closure were abandoned for other techniques (fig. 40) early in the war, because of the poor results (fig. 41). The ribs were approximated while the intercostal bundle was being sutured. The Lambotte bone-holding forceps or a large towel clip proved excellent rib-approximators. Catgut sutures were sometimes used to approximate separated ribs and reduce the size of the costal opening.

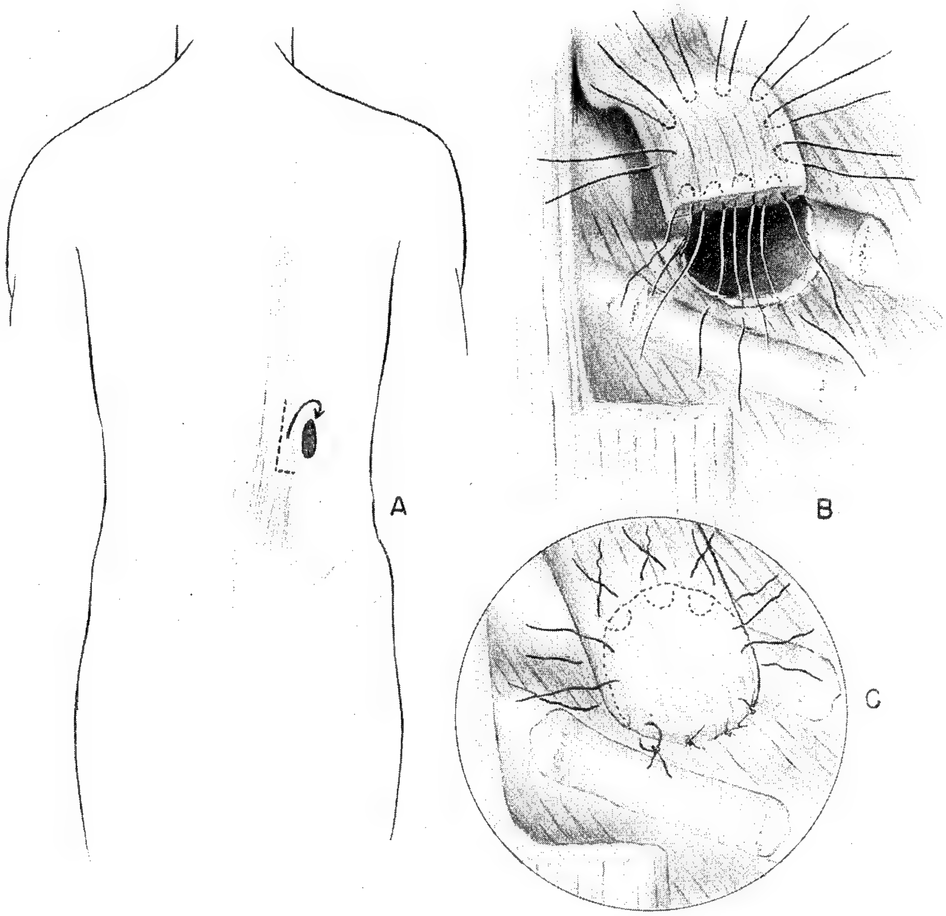

FIGURE 37.—Closure of wound with swinging flap of erector spinalis. A. Location of defect in lower posterior chest wall. B. Details of technique. Sutures placed in erector spinalis flap. C. Flap sutured in place. (Note substitution of erector spinalis for paraspinalis.)

Relaxing incisions at a distance from the wound were often a great help in closure. Extensive dissection and freeing up of the subcutaneous tissue were also helpful.

5. The use of skin and fascia to effect closure was always an undesirable improvisation, since it left an unstable and unsupported chest wall. When this technique was used, pressure dressings were necessary to strengthen the wall. Usually a plastic procedure, with a fascial graft or prosthesis, had to be employed later, at the base hospital or in the Zone of Interior, to re-create a stable thoracic cage and prevent herniation of the lung.

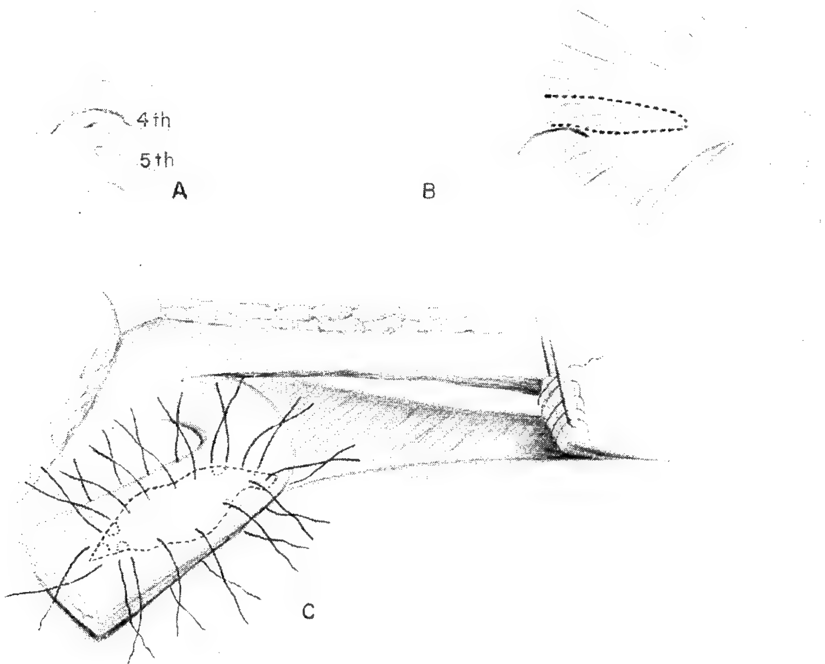

FIGURE 38.—Closure of anterior wound complicated by sternal defect with pectoral muscles. A. Location of sternal defect. B. Schematic showing of relation of pectoral muscle to sternal defect. C. Detail of coverage, showing developed pectoral flap.

6. The diaphragm was occasionally employed to close certain strategically located defects in the lower thoracic cage. It was also sometimes paralyzed by crushing the phrenic nerve, in the belief that it was helpful to decrease the size of the hemithorax and thus lessen the strain on a large wound during the immediate postoperative period. Neither method was generally popular.

The skin wound was usually left open, to be closed a few days later in a general hospital at the base. In many instances, primary suture at initial wound surgery would have been entirely safe. It was never possible, however, to determine the potential virulence of a latent infection which might be present in the wound at the time of initial debridement, and the infectious complications that arose in some cases in which primary closure was done more than offset any gains accomplished by this technique. It was with good reason that delayed primary wound closure became theater policy.

Dressing.—The dressing was of great importance in wounds of the chest wall. Maximum support was provided by the liberal use of wide Ace ban-

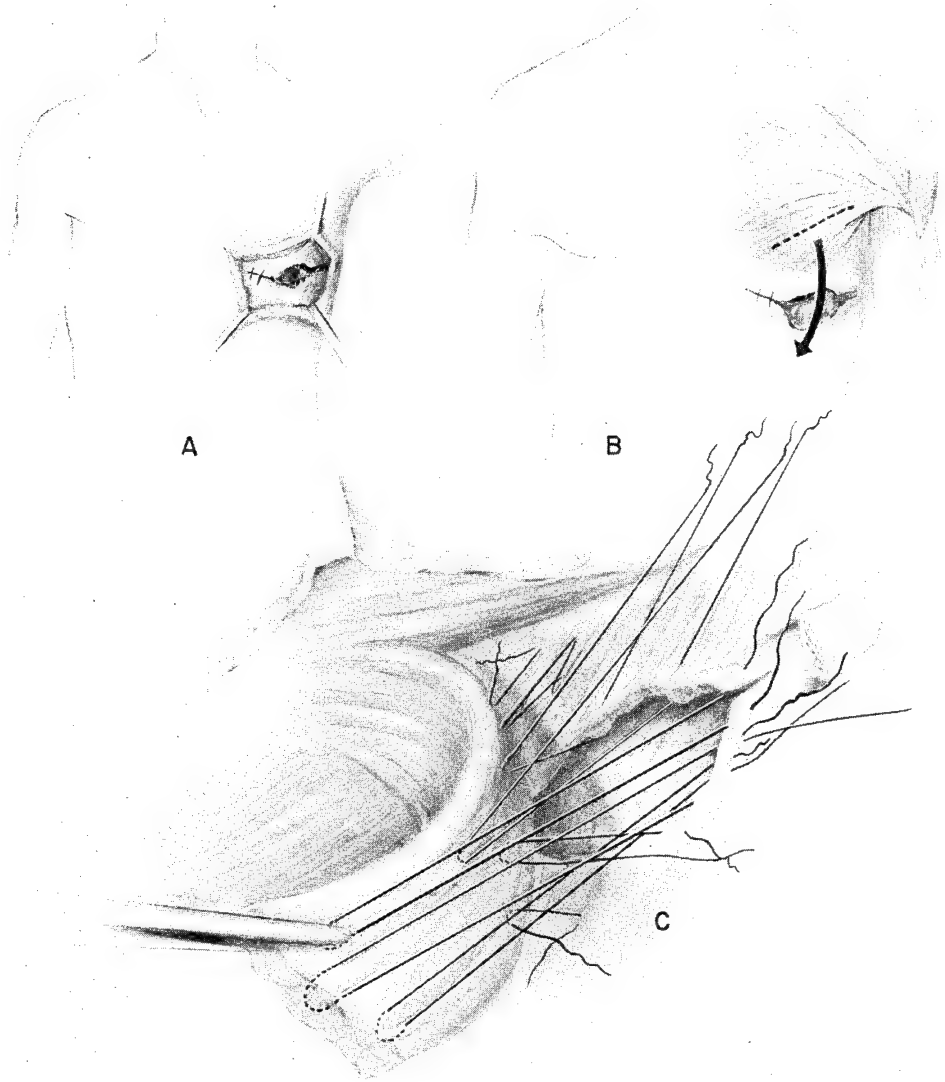

FIGURE 39.—Closure of large anterolateral sucking wound. A. Wound after debridement. B. Schematic showing of development of pectoralis major flap. C. Closure of wound with pedicled flap of pectoralis major.

dages or of adhesive applied up to, or beyond, the midline, both anteriorly and posteriorly. The skin was first painted with tincture of benzoin or some other adherent, to provide good traction and to prevent the blistering likely to occur when an adhesive dressing was applied tightly without this precaution.

A properly applied supportive dressing, put on without tension, reduced paradoxical motion of the chest; kept the muscles of the thoracic cage in physiologic approximation; and, by reducing pain, made the patient willing to cough and thus aided in the expectoration of material from the tracheobronchial tree.

FIGURE 40.—Technique of approximating ribs and securing airtight closure of interspace without use of pericostal sutures. Care had to be taken to avoid crushing intercostal nerves.

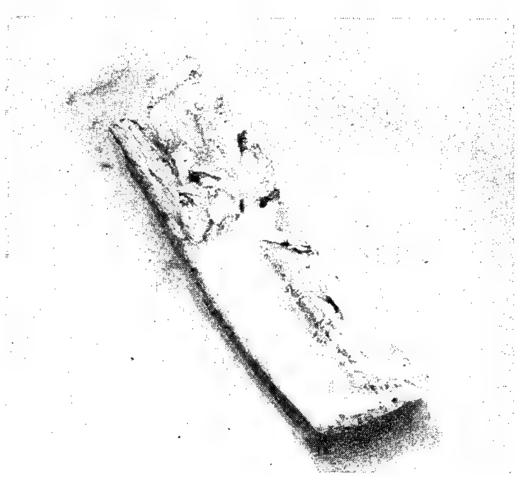

FIGURE 41.—Section of rib 2 weeks after catgut suture had been placed around it.

Local Chemotherapy

The practice of using local sulfonamide therapy at operation was rather general when the war began. From 5 to 10 gm. of crystalline sulfonamide was used in the pleural cavity and in the wound, depending upon the contamination found at operation. This was a matter of individual practice, not a theater recommendation, and the policy was gradually discontinued because its tendency to cause increased and often troublesome fluid production more than offset any possible bacteriostatic effect. It was also found that sulfonamide powder at times caused granulomas of the wound and delayed healing.

A few surgeons considered local sulfonamide therapy of great value. A number considered it harmful. The majority believed that whether it was used or not made no difference at all. Its general use never reached prewar expectations. Even before penicillin became available, there was a growing belief that systemic chemotherapy was all that was necessary, and it was also believed that the sulfonamides might play some part in renal shutdown (lower nephron nephrosis), which was occurring with disturbing frequency in association with profound shock.

After penicillin was introduced, it became the rather general practice to instill it into the pleural cavity at the end of any intrathoracic operation, in 25,000- to 50,000-unit amounts, in 25 cc. of physiologic salt solution. If the infection was severe or mixed, sulfanilamide was sometimes used with penicillin. Later, this practice was also discontinued. There was never any conclusive proof of its efficacy, and most surgeons came to believe that as much was probably accomplished by systemic penicillin, in full doses. Neither local nor systemic chemotherapy nor antibiotic therapy was regarded as a substitute for extensive and thorough debridement and other sound surgical practices.

TRAUMATIC THORACOTOMY

In traumatic thoracotomy, as the term implies, the wound itself and the debridement that was a necessary part of its management provided the entrance into the pleural cavity.

In a formally planned thoracotomy, the incision was sometimes made through an extension of the original wound if the latter was so located that the necessary surgery could be carried out through it. If there was considerable damage to the ribs, the incision could be made through the bed of a resected rib. In the absence of costal damage, an intercostal incision was used. The location of the incision depended upon only one consideration, gaining the maximum exposure for the necessary manipulations. The traumatic wound was therefore not used unless, with only slight extension, it offered satisfactory exposure.

If there was need for access to a part of the chest not readily available through an enlargement of the original incision, there was no hesitancy, after debridement had been performed, in making an elective incision that would give the desired access. If, for instance, a bullet entered the upper right chest and finally lodged in the lower lobe of the right lung, the wound of entrance was closed, and a formal intercostal thoracotomy was done at the level that would be optimum for examination of the entire right lung as well as for removal of the foreign body.

Anterior thoracotomy was discarded early in the Mediterranean experience. An incision in the thin tissues of the anterior chest wall frequently broke down, and the exposure was not so good as that secured by other incisions. By the end of the war, an anterior incision was seldom used except in traumatic thoracotomies and in an occasional cardiac wound in which it gave the necessary exposure. If it was used, an intercostal incision was preferred to rib resection, which inflicted further damage on the thoracic wall and with which closure was not as satisfactory. If an intercostal incision was used, the introduction of two rib-spreading Army-type retractors, with slow spread of the ribs, produced excellent relaxation of the chest wall and adequate exposure without rib fracture. Some surgeons carried out intercostal block with procaine hydrochloride (Novocain) before spreading the ribs. Proponents of these techniques believed that they hastened recovery and greatly reduced postoperative pain.

ELECTIVE THORACOTOMY

In the Mediterranean theater, the policy was to employ a posterolateral approach for practically all elective thoracotomies (fig. 42). It permitted satisfactory access to most of the chest structures and closure with it was seldom difficult.

A technique developed by Maj. Thomas H. Burford, MC, and suggested by Col. Frank B. Berry, MC, utilized a shortened posterolateral incision through the intercostal bundle, without costal section or resection (figs. 43 and 44). As experience accumulated, it became apparent that section of the serratus anterior was not necessary; simply reflecting it served the purpose equally well. In more than 200 thoracic injuries in which it was used, this technique provided entirely adequate exposure for the management of all types of wounds that required thoracotomy. Thoracolaparotomy, extensive decortication, lobectomy, and complete hilar dissection were accomplished through it.

A wound of the anterior superior chest presented a particularly difficult problem if it was necessary to expose the large vessels in the superior mediastinum and at the base of the neck. The mediastinal portion of the procedure

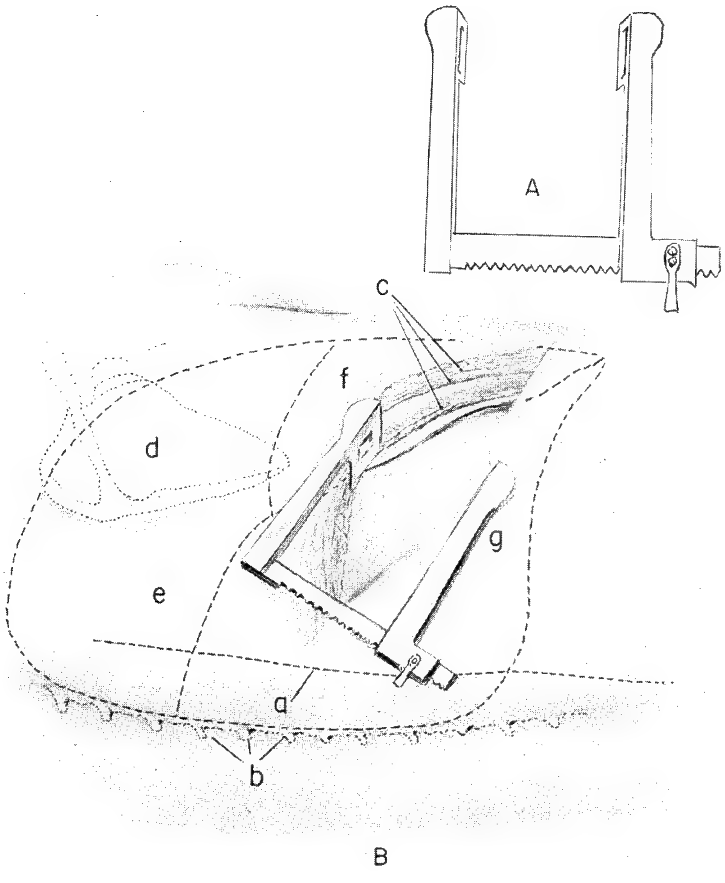

FIGURE 42.—Exposure of thoracic cavity with rib-spreader in posterolateral thoracotomy. A. Rib-spreader. B. Rib-spreader in situ, with gentle spreading of ribs, showing: Erector spinae muscle group (a), spinous processes (b), divided latissimus dorsi, serratus anterior, and intercostal muscles (c), scapula (d), right upper pulmonary lobe (e), right middle pulmonary lobe (f), and right lower pulmonary lobe (g).

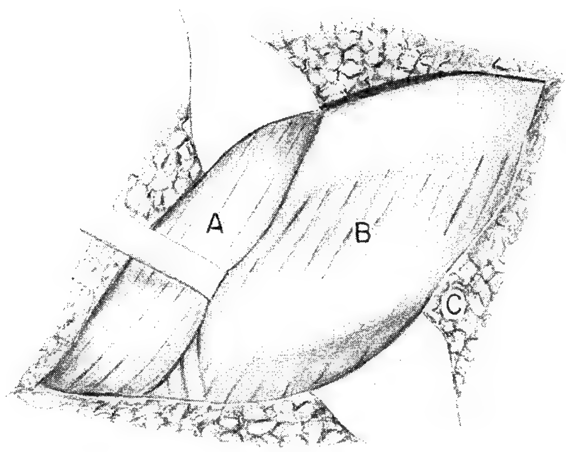

FIGURE 43.—Burford technique of traumatic thoracotomy, using shortened posterolateral incision. A. Serratus anterior muscle. B. External intercostal muscle. C. Cut edge of latissimus dorsi muscle. (Note method of reflecting serratus anterior muscle. Thorax is entered through intercostal bundle.)

could be managed quite well intrathoracically except that the exact point of injury was frequently not determined before operation. It was therefore necessary to provide exposure of both the cervical and the mediastinal portions of the vessels. This was best accomplished by a curving anterior incision, which permitted access to the base of the neck, the clavicle, and the sternum unilaterally (fig. 45). After the clavicle had been sectioned, with Gigli's wire saw if it was available, a portion of the manubrium, with the sternoclavicular joint, could be reflected outward. All the major vascular structures could thus be exposed, and, if the pleura had not shared in the damage, the operation could be done extrapleurally.

Details of the management of wounds of the lung (vol. II, ch. I), foreign bodies (vol. II, ch. VII), cardiac wounds (vol. II, ch. II), and other special injuries are described under the appropriate headings.

Closure was effected by the same general principles described for debridement (p. 275).

FIGURE 44.—Burford technique of traumatic thoracotomy. Closure without pericostal sutures. A. Lambotte rib clamp in place, approximating ribs. B. Closure of intercostal bundle, with removal of clamp.

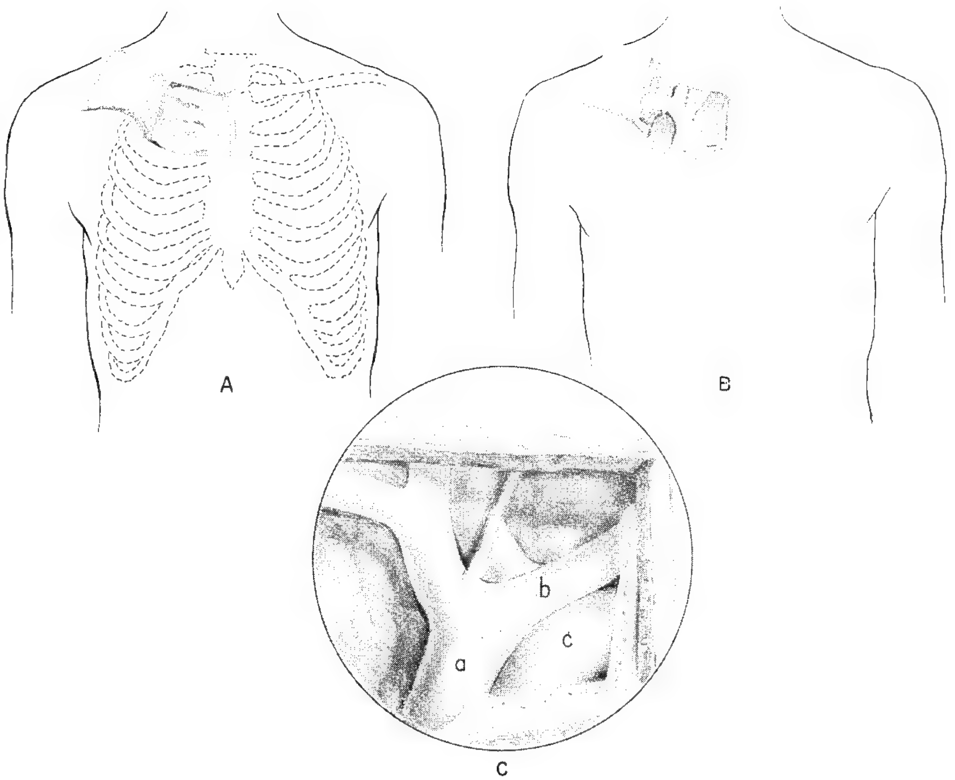

FIGURE 45.—Exposure of large vessel in superior mediastinum and at base of neck by modified Harken technique. A. Curving anterior incision exposing base of neck, clavicle, and lateral half of sternum. B. Schematic showing of section of manubrium and lateral retraction of flap. C. Exposure of major vessels showing superior vena cava (a), left innominate vein (b), and arch of the aorta (c).

SPECIAL TECHNICAL CONSIDERATIONS

Lavage of the pleural cavity.—After intrathoracic procedures had been completed, all blood, blood clots, and other detritus were removed from the pleural space. As a rule, most of it could be removed by the suction tip. A certain amount, however, was likely to escape detection by this method, and the surgeons of the 2d Auxiliary Surgical Group early came to believe that thorough lavage with physiologic salt solution at body temperature was a more satisfactory plan. From 1,500 to 2,000 cc. of solution were introduced, but the amount of fluid used was not important. What mattered was that lavage be continued until the fluid returned clear and it could be assumed that all blood and blood clots that could be removed had been washed off the pleural lining.

The thoracic surgeons of the 2d Auxiliary Surgical Group had used this technique in civilian practice, and they believed that when it was employed, the postoperative effusion was reduced in amount and convalescence was smoother. The use of gauze sponges, even soaked in physiologic salt solution,

to remove blood and blood clots from the delicate pleural surfaces was less satisfactory. The use of gauze, however gently it was employed, was certain to produce some degree of trauma, add to the amount of postoperative pleural exudation, and predispose to the formation of pleural adhesions when the lung and thoracic wall came into apposition.

A few surgeons did not accept this point of view and omitted lavage after thoracotomy, on the ground that a small amount of blood left in the pleura after aspiration would not serve as a pleural irritant. This concept was contrary to the concept prevalent as far back as World War I. Yates (*1*), in the history of the U.S. Army Medical Department in that war, cited Delrez' and Middleton's demonstration that blood in contact with the serosal membrane in the chest (and in the joints) is so irritating that it can provoke a serofibrinous serositis. In Yates' own opinion, any irritation of the pleural serosa provoked a very rapid serous effusion accompanied by hemothorax, the amount of fluid thus formed soon exceeding the amount of blood originally present. In view of Yates' sound approach to the problem of hemothorax, it is difficult to understand his further statement that lavage of the pleural cavity was a temptation to be resisted, as healing after it was poor. Very few of the thoracic surgeons in the Mediterranean theater shared this point of view.[1]

Nerve block.—While a few thoracic surgeons advocated and practiced crushing of the phrenic nerve at thoracotomy, to prevent postoperative pain, the majority believed that this was a certain way to induce paresthesis and anesthesia, which could be considerably more troublesome than pain.

As their experience increased, however, thoracic surgeons routinely performed intercostal nerve block at operation, going at least two nerves above and two below the site of injury. The decrease, or complete elimination, of pain after operation permitted the patient to breathe deeply and cough freely, and this prophylactic measure prevented many postoperative complications. A few surgeons preferred to perform intercostal nerve block by the paravertebral technique.

Manual reexpansion of the lung.—Frequently, while the anesthesiologist was using positive pressure to expand the lung after intrathoracic surgery had been concluded (p. 264), it was observed that the lateral portion of the lower lobe did not expand as readily as the remainder of the lung. When the patient was lying on his side, partial collapse of the lung allowed a folding-over of this portion onto the diaphragmatic surface of the lower lobe. When the infolded portion was pulled out and unfolded manually, aeration promptly became satisfactory. The temporary manual blocking of an upper lobe bronchus, for example, sometimes allowed most satisfactory expansion of a lower lobe that was slow to expand.

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[1] As a matter of historical record, mention should be made of the animal experiments, on dogs and goats, carried out at the University of Chicago, to determine the effect on blood plasma proteins of filling the pleural space with plasma after loss of varying amounts of lung. The experiments were carried out by Adams and Thornton, whose final report was made to the Committee on Medical Research, Office of Scientific Research and Development, 28 Sept. 1943 (*2*).

Drainage.—In the early months of fighting in the Mediterranean theater, drainage was instituted routinely in lacerations of the lung, abrasions of the parietal pleura, or contamination of the pleural cavity. This was in line with the established medicomilitary policy that all thoracic wounds should be drained intercostally. An intercostal tube, however, seldom functioned more than 48 hours, and if there was fluid in the chest, aspiration then had to be employed. As the war progressed, the policy of routine drainage was replaced by the use or omission of drains according to the indications of the individual case. The decision depended not only upon the type of wound but also upon the location of the hospital, the adequacy of nursing care in it, and the surgeon's personal experience in chest surgery. If there was any question of pulmonary lacerations or pleural soiling, drainage was always instituted.

If drainage was omitted, great pains were taken to secure complete reexpansion of the lung at the time of closure; apposition of the lung with the thoracic cage was of paramount importance. The following technique was usually employed:

As pleural closure was begun, the anesthesiologist gently increased the intrabronchial pressure to between +5 and +10 cm. H_2O. A No. 22 F. catheter, with at least two openings in the tip, was inserted through an opening between the sutures and was so placed as to lie in the uppermost portion of the chest. An air vent had previously been made in the catheter near the proximal end, to prevent undue suction which might damage the lung. Most thoracic surgeons did not consider it necessary to use a suction machine attached to the catheter. Attachment of the catheter to a tube with its end in a basin under water allowed all the air to bubble out. The catheter could thus be removed, and the sutures in the chest wall at the site of insertion of the catheter could be quickly tied.

By the time pleural closure was completed, the anesthesiologist had increased the intrabronchial pressure to between +15 and +20 cm. H_2O. At the same time, the degree of suction was increased by digital occlusion of the hole in the catheter. The positive pressure created by the anesthesiologist and the negative pressure created by suction on the catheter usually resulted in good expansion, and when the sutures in the muscle layer were tied, the chest became airtight. After these sutures had been tied, a suture was placed around the catheter by the assistant, and it was slowly withdrawn. Then this suture was tied.

If drainage was to be employed, these precautions were not necessary, since any residual air or fluid would be expelled through the drains. It was a wise precaution, however, for the anesthesiologist to expand the lung at least once just before the wound was closed, to be certain that expansion was possible.

When drainage was considered necessary, it was preferably accomplished with two outlets (fig. 46). The first outlet was either a large rubber catheter (No. 28 or No. 30 F.), with two openings cut on each side, or standard issue red rubber tubing, $\frac{1}{4}$ inch in diameter, with a $\frac{1}{16}$-inch wall (Catalog No. 3878000). The end was beveled, and three or four holes were cut in the distal

2½ inches. A drainage tube of this size allowed for the escape of thick, bloody fluid. The second drainage tube, a smaller catheter, preferably of the mushroom type, was placed anteriorly in the second intercostal space to allow the escape of trapped air.

The lower catheter was not placed any farther posteriorly than the posterior axillary line or more dependently than the ninth intercostal space. Drainage through the seventh or eighth intercostal space was usually practical, since the absolute dependency essential for drainage in empyema was not necessary as a postoperative measure in an uninfected wound.

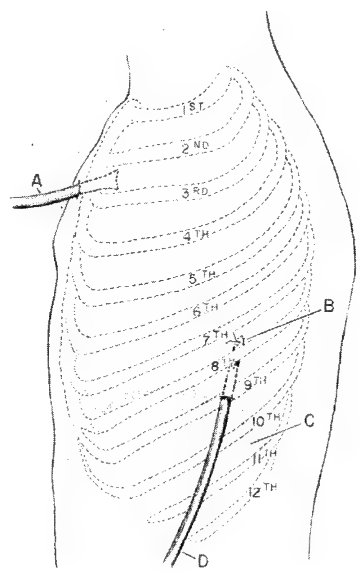

FIGURE 46.—Sites of drainage and techniques of placement of intercostal drainage tubes. External portion of tubes connected to water-seal bottles. A. Small de Pezzer catheter, with end cut out, in second interspace. B. Tube tacked to parietal pleura. C. Diaphragm. D. Fenestrated rubber tubing inserted into pleural cavity through eighth interspace in posterior axillary line.

The lower catheter was inserted through a small stab incision made at right angles through the selected intercostal space after the skin had been drawn sharply upward. The distal 2½ inches of the tube were pulled into the pleural cavity before the skin was released. With this maneuver, the intrapleural portion of the tube tended to lie slightly angulated and upward. When the tube was removed later, there was no opportunity for air to enter. In persons with a thin chest wall, the use of a loose stitch, to be tied when the tube was removed, prevented ingress of air.

After the tube had been introduced, it was pushed into contact with the parietal pleura. The tip of the beveled portion was then tacked down with a fine suture. If this was not convenient, the catheter could be held in place by looping a suture over it and tying the suture over a small gauze bolster outside of the skin. Whatever technique was used, the object was to make certain that the intrathoracic portion of the tube lay flat and unkinked along the parietal pleura.

The smaller drainage tube, which was placed in an upper anterior intercostal space, served as an air vent. It was thought that reexpansion was more rapid and more certain when it was used.

If penicillin had been instilled into the chest, the posterior drain was clamped off for from 6 to 8 hours. Water-seal drainage was employed. Wangensteen suction was occasionally used to help remove the fluid and hasten reexpansion of the lung.

CATHETER SUCTION AND BRONCHOSCOPY IMMEDIATELY AFTER OPERATION

Though the bronchial tree was kept as dry as possible by the anesthesiologist, by suction during operation, aspiration was repeated before and during removal of the endotracheal tube. By this time, the patient was usually beginning to react and was likely to cough, from the tracheal stimulation caused by the manipulations. He thus aided in the removal of material beyond the reach of the catheter.

Whether bronchoscopy was necessary routinely at the conclusion of operation remained a matter of dispute until the end of the war:

Those who advocated routine bronchoscopy doubted that even repeated tracheal aspiration through a catheter passed through the endotracheal tube would completely clear the airway of blood and mucus. They regarded catheter aspiration as a blind procedure at best, in which it was impossible to be certain that both main stem bronchi had been adequately aspirated. They pointed out that at times it was difficult to pass a catheter into the left main bronchus, so that large amounts of material were frequently brought up through the bronchoscope after apparently satisfactory catheter aspiration (p. 291). They considered bronchoscopy as particularly necessary if there had been gross blood or clots in the tracheobronchial tree during operation.

Opponents of routine bronchoscopy took the position that when a competent anesthesiologist thought that he had cleared the air passages by catheter suction, no significant amount of blood or other material was likely to be brought up by bronchoscopy. This group of chest surgeons preferred to reserve this procedure for patients with excessive tracheobronchial bleeding and for the few cases in which resistance offered to pulmonary reexpansion raised doubts concerning the patency of the bronchi.

Both groups, of course, advocated immediate bronchoscopy if the stomach had not been properly emptied before operation and the patient vomited. As experience was gained in treating war casualties, it was seldom indeed that a patient was placed on the operating table without prior evacuation of the stomach with a Levin tube.

The persistence of audible moisture through the Magill tube or the failure of complete and prompt pulmonary reexpansion after catheter aspiration was also a positive indication for bronchoscopy.

One objection advanced to routine bronchoscopy was that it required prolongation of the operation and deepening of the anesthetic level. The advocates of the procedure claimed that this argument was not valid because an alert anesthesiologist could so gage the depth of anesthesia that it need not be increased. It was necessary that the jaws be kept separated until the endotracheal tube was removed, and only 2 or 3 minutes were needed from that point to the completion of aspiration by bronchoscopy. Furthermore, deep anesthesia was not required or desirable for this procedure. The patient was kept sufficiently relaxed to permit easy introduction of the bronchoscope, and yet near enough consciousness to be stimulated by its passage, so that he would begin to cough.

If the position of the patient on the table permitted, bronchoscopy could be carried out while the wound was being closed or other wounds were being debrided.

There was one risk attached to bronchoscopy in this inbetween stage of anesthesia, the so-called vagovagal reflex, which was practically always associated with hypoxia. It was a general practice in civilian surgery to administer atropine (gr. 1/100 or 1/75) just before bronchoscopy was undertaken because this drug effectively blocks this reflex. This was not the routine practice in the early days of the Mediterranean theater, but after two deaths from this cause (p. 266), the policy was promptly instituted and became routine in all hospitals of the theater. These two deaths, the only ones in 436 patients in the 2d Auxiliary Surgical Group experience treated by bronchoscopy immediately after operation, represented a negligible risk, which might possibly have been eliminated by the use of atropine. Against these fatalities were the many deaths from postoperative complications probably prevented by bronchoscopy.

Failure of catheter suction was a factor of supreme importance in several cases in which recovery was complicated, and it was known to be directly responsible for at least one death:

Case 1.—A 41-year-old staff sergeant, who was somewhat overweight and barrel-chested, sustained a large posterior sucking wound of the right chest, with multiple rib fractures, 13 November 1944 at 0903 hours. Debridement was done at 2100 hours the same day. The operation was difficult and took 2½ hours. The pulse rate gradually increased during the operation, and there were several periods of cyanosis, which were relieved only by positive pressure anesthesia. Frequent aspirations through the endotracheal catheter produced only small amounts of bloody mucus. The patient died on the operating table, at the end of the operation, while bronchoscopy was being performed. The left stem bronchus was filled with blood and tenacious fluid, and the left lung was completely atelectatic. The right stem bronchus was relatively free of fluid.

Comment.—This death could probably have been prevented had the essential pathologic process been recognized during operation by the surgeon and anesthesiologist and had bronchoscopy been employed without delay. It is also possible that the blocking of the left stem bronchus existed before surgery and that preoperative bronchoscopy would have insured successful anesthesia and surgery. It was consistently more difficult, as this case shows, to aspirate fluid from the left stem bronchus than from the other bronchi.

COMPLICATIONS DURING SURGERY

Aspiration of vomitus.—Aspiration of gastric contents during operation was an uncommon occurrence because vomiting was uncommon: Emptying of the stomach in the shock tent, as already pointed out, was part of the preoperative routine, and after it had been completed, the gastric tube was usually left in situ.

When vomitus was aspirated, immediate action was necessary. Fatal bronchial obstruction could develop, especially if food particles were present in the vomitus, and fatal asphyxia could supervene rapidly. Gastric contents are extremely irritating to the respiratory tract, and their presence excited an immediate, severe exudative chemical bronchitis and bronchiolitis. Without their prompt removal, a fulminating pneumonitis developed.

If vomiting occurred before the patient had completely reacted from the anesthetic, so that his cooperation could not be secured, no time was wasted in attempts to make him cough. Bronchoscopy was performed immediately because it permitted visualization of the bronchi and facilitated the removal of particulate matter. An intravenous injection of atropine was given (gr. 1/100) if no atropine had been given within the hour, to minimize the possibility of vagovagal reflex.

Cardiac standstill.—Cardiac standstill was an infrequent complication of surgery in World War II. Prolonged hypoxia and shock before surgery, inadequate preoperative preparation, obstruction of the airway, poor ventilation, and blood loss during surgery were all important in its development. As experience was gained, casualties were brought to surgery in better condition and carried through operation in a better physiologic state; cardiac standstill became extremely uncommon. Probably the most important factor in reducing the risk of cardiac arrest was careful preoperative preparation (p. 237).

POSTOPERATIVE MANAGEMENT

The military experience amply corroborated the long established view that nowhere in surgery is proper postoperative care more essential to a good end result than in chest surgery. The functional level to which the patient was restored, as well as the number and extent of postoperative complications and later sequelae with which base surgeons were required to contend, was dependent, in large measure, upon the efficacy of postoperative management.

Immediate Measures

It was routine, in seriously wounded patients and in those in less than satisfactory condition, to continue transfusion during operation as well as afterward.

Patients in poor condition at the end of operation were frequently left on the table for an hour or more while additional blood was administered and oxygen was given by the intratracheal tube, Boothby-Lovelace-Bulbulian mask,

or nasal catheter. It helped to prevent the anoxia that was the greatest hazard at this time.

There were three principal objectives of immediate postoperative care:

1. To bring the lung into apposition with the chest wall as rapidly as possible. This goal, which was essential to restore normal intrathoracic physiology and prevent empyema, was usually achieved by the use of positive pressure by the time the wound was closed.

2. To relieve pain, so that the patient would be able to maintain optimum respiratory excursions and to cough effectively.

3. To maintain a clear airway, to prevent pulmonary complications from retention of secretions.

When these requisites were fulfilled by the adoption of special measures to accomplish them, convalescence was usually as smooth as the intrinsic nature of the injury permitted.

Relief of pain.—It was imperative that the patient move the chest wall after operation. His respirations had to be full and deep, and he had to cough and raise the secretions collected in the tracheobronchial tree. Both of these acts were attended with pain unless intercostal nerve block had been performed at operation (p. 246). Then this problem did not arise. If pain recurred, it could be controlled by repetition of the nerve block, which could be done without moving the patient from his bed. The effect of a single injection usually lasted for 24 hours or more, and the procedure could be repeated as often as necessary. When a patient could cough without pain, as he could when the intercostal nerves were blocked, he could usually clear his bronchi satisfactorily by his own efforts.

The effects of nerve block were longer lasting than the effects of morphine would have been. Morphine was contraindicated in these circumstances. As pointed out elsewhere (p. 246), it had undesirable effects in thoracic injuries and even more undesirable consequences after operation.

Clearance of the tracheobronchial tree.—Patients were turned at regular intervals after operation until they could move themselves. Ward attendants periodically urged them to cough, in order to evacuate secretions. They helped them to sit up, and they supported the chest manually during attempts to cough. In these ways, the importance of coughing was stressed and the patients' cooperation was secured.

An increase of bronchopulmonary secretions was usual immediately after operation. If there was a preexisting bronchitis, as there frequently was during the late fall and winter, the secretions were likely to be semipurulent or purulent. If coughing was not effective and fluid was retained, the signs, in addition to a frequent, ineffectual cough, were rattling respirations, dyspnea, and sometimes cyanosis, which was a late manifestation. If the bell of a stethoscope was placed over the patient's mouth and his respirations listened to, it was easy to recognize the presence of retained tracheobronchial secretions.

When these signs appeared, an intratracheal catheter was introduced at once, and aspiration was performed at regular intervals. The expulsive effort

which resulted from its introduction forced small plugs of material out into the larger bronchi, whence they could be removed by suction.

If catheter suction was not successful, bronchoscopic aspiration was considered to be necessary. Whenever there was doubt as to the need for bronchoscopy, the doubt was interpreted as an indication for its use. It was particularly indicated if the amounts of fluid in the tracheobronchial tree were excessive and if the patient had only partly reacted from anesthesia and the muscles of his neck and jaw had become stiff and rigid. Although bronchoscopy was a more complex technique than catheter suction, it could be performed without moving the patient from his bed.

Thoracentesis.—As already mentioned, surgeons who did not drain the pleural space after forward surgery were in the minority, though a few with wide experience preferred to rely on thoracentesis. When drainage was omitted, reexpansion of the lung was maintained by the continued use of thoracentesis as long as 100 cc. or more of fluid or air was obtained by this procedure. Close postoperative observation was necessary in these cases. Some patients required no postoperative aspiration, while others required it for several days or even a week or more.

The objective of both groups of surgeons—those who used drainage and those who did not—was to obtain a dry pleura and a reexpanded lung as quickly as possible. When the techniques of drainage and thoracentesis were employed correctly, there was no discernible difference in the results accomplished.

Management of drainage tubes.—Drainage tubes were milked at least once or twice daily to maintain their patency, but major adjustments and irrigations through them were avoided as increasing the risk of infection. The tubes were removed as soon as they had ceased to function, which was usually within 48 hours after operation.

It was a strict rule that no patient be evacuated with an intercostal catheter in situ. It was learned early in the war that water-seal drainage was not only unsatisfactory but dangerous during evacuation, whether the bottle was connected to a needle or to a catheter.

General Routine of Management

The remainder of the postoperative routine was, in general, much the same as after any serious chest operation:

Replacement therapy.—The indications for the administration of blood, plasma, or both were the same as during resuscitation. Plasma protein and hematocrit determinations frequently revealed surprisingly low levels, even in patients who had had large amounts of blood administered before and during operation. Even in these circumstances, great care was taken not to overload the cardiovascular system, particularly in blast injuries, in which pulmonary edema was readily precipitated. It was desirable to keep the fluid intake by all routes at 2,500 cc. each 24 hours, so that the urinary output would be at least 1,000 cc. during this period. This output was regarded as the essential mini-

mum when sulfadiazine was being given. The general policy was to give electrolytes in as small quantities as would be adequate.

Precautions against thrombosis and embolism.—Thrombosis and embolism were not frequent complications in chest wounds, though they could occur, just as in any other wound. They were sometimes present as a complication of associated wounds.

The usual precautions against embolism were employed routinely. The patient's position was changed frequently. Fowler's position, which tends to cause some obstruction to the return flow of blood from the extremities, was not maintained for long periods. Simple exercises for the feet, legs, and thighs were begun the day after operation if local injuries did not contraindicate them. The lower extremities were examined daily, with a careful search for Homans' sign on each examination.

Roentgenologic examinations.—Clinical observations during the postoperative period were supplemented by roentgenograms to demonstrate pulmonary reexpansion and the presence of air and fluid in the chest. Anteroposterior and lateral films were usually taken on the fourth or fifth day after operation, with the patient in a sitting position. They were taken at other times as necessary, but always within 48 hours of the time the patient was to be evacuated.

CHEMOTHERAPY AND PENICILLIN THERAPY

The Sulfonamides

Before penicillin became available in the spring of 1944, sodium sulfadiazine (1 gm. every 4 hours) was given as long as fever persisted and until the pleural space was free of fluid. To meet these requirements, it usually had to be given for from 10 to 14 days. Special precautions for the use of the sulfonamides were detailed in a medical circular issued by the Office of the Surgeon, Fifth U.S. Army, in January 1944 (*3*). In this circular, attention was called to the fact that most patients observed up to this time with anuria going on to lower nephron nephrosis had received sulfadiazine intravenously in 5-gm. doses. Precautions were laid down for its local use (not more than 10 gm.), and for withholding intravenous sodium sulfadiazine therapy until 24 hours after operation, after the patient had reacted from anesthesia and shock. Then the dose was not to exceed 2.5 gm. every 12 hours. Sulfonamide therapy was to be promptly discontinued if the 24-hour urinary output was less than 1,000 cc. or if gross or microscopic hematuria developed. Fluid intake was to be adequate to insure a minimum urinary output of 1,500 cc.

Since lower nephron nephrosis continued to occur in spite of these precautions, it is doubtful that sulfonamide therapy played any major role in its development. This theory was borne out by the later studies of the Board for the Study of the Severely Wounded, which produced no evidence to show that the sulfonamides played any part in the renal dysfunction (*4*).

Studies on shock in the Mediterranean theater by Maj. (later Lt. Col.) John D. Stewart, MC, and his associates (*5*), indicated that sulfonamide levels in the blood were "erratic and uncertain." These observers warned that this "unpredictability" should be kept in mind in any appraisal of the presumed benefits of routine sulfonamide therapy in severely wounded men. Sulfonamide therapy must be controlled by blood determinations, they warned, if both overdosage and ineffective levels were to be avoided.

The early favorable results achieved in combat-incurred wounds in the Mediterranean theater led the uncritical to attribute them to chemotherapy. Accurate statistical data and control studies do not exist, but careful observation of large series of wounds convinced impartial observers that favorable results were chiefly due to early, adequate debridement, with chemotherapy of little real influence. As the war progressed, it became increasingly evident that the local or systemic use of the sulfonamides did not greatly improve the results accomplished by careful attention to surgical principles.

There was no evidence that the incidence of empyema was significantly less when either local or systemic sulfonamide therapy was employed, though established infections were thought to run a shorter course when the necessary surgery was thus supplemented.

Penicillin

By the spring of 1944, penicillin, which had originally been used only for selected cases, had become available in sufficient quantities to be used in all wounds. The routine was to begin using it as soon as the wounded man reached the battalion aid or clearing station, in the amount of 20,000 units intramuscularly every 3 hours. If it had been omitted in these installations, it was begun as soon as the field or evacuation hospital was reached. It was then continued in this amount after operation, the duration of therapy depending upon the surgeon's decision. Usually, it was given for from 7 to 10 days. If contamination was severe or infection was evident, 50,000 units was sometimes given intravenously in the shock ward and another 25,000 intramuscularly before routine administration was begun.

A few surgeons advocated instillation of penicillin (25,000 units in 25 cc. of physiologic salt solution) after all aspirations of the chest, but this was not an accepted practice.

As experience increased, it became evident that penicillin, like the sulfonamides, was not of great value, and perhaps was not even necessary if debridement had been complete. The opinion also spread that the principal benefit derived from irrigation of the pleural cavity before wound closure was not due to any chemical or antibacterial agent used in the fluid but was due, instead, to the mechanical cleansing thus achieved.

On the other hand, penicillin was of definite value in controlling infection when, for any reason, the removal of all devitalized tissue was impractical or would have resulted in excessive mutilation. Wounds around the shoulder

are an illustration. Penicillin was also of very great value in surgery at the base.

Lack of followup studies makes it impossible to draw any conclusions as to the absolute and relative effects of these various policies. The case fatality rate among teams of the 2d Auxiliary Surgical Group for the second half of 1944, after penicillin had come into general use, was considerably lower than for the first half (25 percent against 34.9 percent) and was still lower in 1945 (20 percent). Penicillin may have played a part in this reduction. It is more likely, however, that the reduced mortality reflects the increased experience of the surgeons in the theater in the management of thoracic and thoracoabdominal wounds; their greater appreciation of the implications and possible complications of chest wounds; improvements in anesthesia; and improvements in preoperative and postoperative care, especially the liberal use of whole blood.

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CHAPTER XII

Reparative Surgery

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GENERAL CONSIDERATIONS

The reparative phase of the management of thoracic wounds was considered to have begun as soon as initial wound surgery had been completed in a forward hospital and the patient was sufficiently stabilized after it to be safely transportable to a fixed hospital. A large experience with these wounds in MTOUSA (Mediterranean (formerly North African) Theater of Operations, U.S. Army), showed that most thoracic casualties could be safely transported to fixed hospitals in the base within a week after initial wound surgery, regardless of the type of operation that had been done in the forward hospital.

As the war progressed, two policies widened the scope, and increased the effectiveness, of reparative surgery. One was the deployment of general hospitals in close support of the Fifth U.S. Army as it moved up the Italian Peninsula. The other was the use of air evacuation, which was first employed in North Africa. These two policies made it possible to institute reparative surgery at a time of maximum benefit for both casualty and theater manpower. The earlier a casualty underwent reparative surgery, the greater were his chances of prompt recovery and the better the outlook for his return to duty within the theater holding period.

The reparative phase of wound surgery, which was developed originally in the Mediterranean theater, furnished another illustration of the intelligent integration of the administrative and professional functions that, together, produced effective continuity of medical care. The procedures of reparative surgery were based on principles designed to prevent or minimize infection and to assure as rapid anatomic and functional restoration to normal as the nature of the wound permitted. Progress in the reparative phase of management of chest injuries was not less significant than was the progress achieved in their initial management.

Mission of Fixed Hospitals and Thoracic Surgery Centers

When policies in the Mediterranean theater were stabilized, casualties with chest injuries who required more than simple wound closure were usually cared for in chest centers. The mission of general and station hospitals and of thoracic surgery centers in base areas has been outlined in detail under those various headings (p. 97).

Specifically, the procedures of reparative surgery for chest wounds carried out in fixed hospitals in the base were:

1. Delayed primary closure [1] of wounds not completely closed at the time of forward surgery.

2. The management of hemothorax, including its complications of clotting, organization, and infection.

3. The management of posttraumatic (hemothoracic) empyema.

4. The performance of pulmonary decortication for organizing hemothorax or hemothoracic empyema.

5. The precise localization of intrathoracic foreign bodies, with their removal on strict indications.

6. The management of complications of thoracoabdominal wounds.

7. The management of other complications related to the chest wound.

Except for delayed primary wound closure, all of these procedures are discussed in detail in the second volume of the thoracic surgery series.

DELAYED PRIMARY WOUND CLOSURE

The dangers of primary closure of battle-incurred wounds of the chest were as great as those of primary closure of other wounds. Since there was no basic difference between soft-tissue wounds elsewhere in the body and wounds of the chest wall or the soft-tissue component of intrathoracic wounds, the policies evolved for the management of soft-tissue wounds elsewhere in the body were entirely applicable to chest wounds and were employed for them.

Indications and contraindications.—As pointed out elsewhere (p. 140), the entire program of delayed primary wound closure in World War II reflected a complete departure from the elaborate bacteriologic concepts and practices by which this technique was employed in World War I. The shift was from emphasis on the flora of the wound, as demonstrated by microscopic and cultural methods, to the gross surgical pathology of the wound, as determined by clinical inspection alone. When the program of delayed primary wound closure was fully developed, the procedure was as follows:

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[1] In the Mediterranean theater, the division of the surgery of combat-incurred wounds into initial wound surgery, reparative surgery, and reconstructive surgery was conceived by Col. Edward D. Churchill, MC, Consultant in Surgery, Office of the Surgeon, Headquarters, MTOUSA, who also introduced the term "delayed primary wound closure" to describe the final step in the closure of combat-incurred wounds. By the spring of 1944, it had become the general practice, at initial wound surgery for thoracic wounds as for other soft-tissue wounds, to leave the skin and subcutaneous tissues open, for later suture in hospitals to the rear. Many surgeons in the theater objected to the nomenclature, on the ground that to employ the words "delayed" and "primary" in juxtaposition was a contradiction in both term and concept. The nomenclature, nonetheless, came into general use in the Mediterranean theater and was adopted by some, though not by all, surgeons in the European theater. It might be added that many surgeons objected, with equal vigor, to the use of the term "secondary closure" for suture of the skin and subcutaneous layers of the wound, on the ground that it implied a previous attempt, which had not been made, to close these layers.

1. A clean wound, in which there was no evidence of infection and in which there was no devitalized sloughing tissue, was considered fit for immediate closure. In most hospitals, the condition of the wound was determined by inspection in the operating room, when the dressings were removed for the first time. In a few hospitals, as already mentioned, it was the practice, when the patient was first examined, to elevate the outer dressing and inspect the wound through the fine-mesh gauze immediately over it. The dressing was then replaced, and the gauze was removed with the dressing in the operating room.

2. A wound that was indurated or showed any other evidence of infection was treated for from 24 to 72 hours before closure by dressings soaked in warm physiologic salt solution.

3. A wound that harbored necrotic tissue or otherwise showed that debridement had been inadequate was treated by redebridement before wound closure, or, if conditions justified it, closure was delayed for several additional days. In the early months of the war, it was repeatedly necessary to redebride wounds in base hospitals because initial debridement had been inadequate or had been omitted. Failure to debride a wound simply because it was small or had been made by a high-velocity missile was found to be an invitation both to wound infection and to pleural infection. Even later in the war when penicillin was available, a subcutaneous area of tissue destruction out of all proportion to the size of the wound of entry was invariably found in these wounds, and many times, direct extension of the infection to the pleural space could be demonstrated.

Timing.—When delayed primary wound closure was first used in the Mediterranean theater, the timelag between wounding and closure was often from 15 to 21 days. This was too long. At the end of this period, scar tissue had frequently developed, and excision of the wound was necessary to effect satisfactory closure.

As time passed, initial debridement became more effective, and the advantages of earlier wound closure were increasingly appreciated. The timelag was successively reduced, first to from 7 to 10 days and later to from 5 to 6 days. When closure was accomplished within these time limits, suture approximation was frequently all that was necessary.

Results.—The policy of delayed primary closure of wounds that had been properly debrided in forward hospitals was attended with generally good results. At the 53d Station Hospital, Bizerte, for instance, there were 125 primary unions in the first 144 chest injuries treated by this technique. The average time from wounding to final closure was 14 days. While no controlled studies were carried out, an analysis of roughly comparable groups of injuries indicated that approximately 7 weeks' time was saved in wound healing when delayed primary wound closure was employed. The use or omission of local sulfanilamide therapy did not alter results to any significant degree. There were 8 failures in 15 closures undertaken on 3 patients (5 closures on each

patient), which suggested to the surgeons that not more than 3 closures should be attempted at a single sitting unless there was a complete change of gloves and instruments.

There were 111 primary unions in 118 wound closures carried out at the 21st General Hospital, Bou Hanifia, Algeria. The explanation of the seven failures was as follows:

1. Incomplete debridement, with foreign bodies and small bits of necrotic muscle left in situ to serve as sources of infection.
2. Unrecognized infection present at the time of closure.
3. Undue delay in closing the wound, thus permitting scar tissue to form.
4. Closure under tension, chiefly due to insufficient undermining of the wound edges before closure. In two or three of these cases, the use of small split-thickness skin grafts would have been wiser. This was another technique which often saved weeks of healing time.

As the figures in these 144 cases show, once the indications and contraindications for delayed primary wound closure had been established, primary healing was the rule. The technique had a number of other advantages:

1. Whatever other reparative procedures were necessary could be carried out in a solidly healed chest wall, which was found to be an essential protection against wound infection and subjacent pleural contamination.
2. The use of this technique materially increased the number of reparative procedures that could be completed within the period of the theater holding policy.
3. This technique permitted turnover of hospital beds at a rate previously unobtainable, and the patients were in generally better condition when they were evacuated to a reconditioning center or to the Zone of Interior for further treatment.

Chemotherapy and antibiotic therapy.—The excellent results secured in the first cases of delayed primary wound closure led some uncritical observers to ascribe them to the use of the sulfonamides. The later results were sometimes ascribed, equally uncritically, to the use of penicillin. It would have been desirable, from a research standpoint, to run control series, in which these agents were withheld from alternate patients whose wounds were serious enough to require them, but this was obviously unthinkable. There was no doubt, however, in the minds of experienced surgeons, that the value of both chemotherapy and antibiotic therapy was far less than the value of adequate debridement. In their opinion, it was that procedure that made delayed primary wound closure so successful.

REPLACEMENT THERAPY

In spite of vigorous transfusion therapy in forward areas, the majority of thoracic casualties arrived in base hospitals with hematocrit values well below normal. It was the practice to give daily transfusions of from 500 to 1,000 cc. of blood until a hematocrit value of at least 40 was reached. This often

required several transfusions. In one group of 648 casualties, 1,047 transfusions of 500 cc. each were required, an average of 800 cc. per patient.

If major reparative surgery was performed, the need for whole blood was greatly increased. The amount required varied with the magnitude of the procedure. Thoracotomy for the removal of an intrathoracic foreign body usually required, in the absence of complications, no more than 1,500 cc., including the amounts administered before, during, and after operation. A difficult, time-consuming thoracotomy usually required at least 2,500 cc., and as much as 4,000 cc. was necessary in many cases.

REPARATIVE SURGERY AND THE LEARNING CURVE

An evaluation of reparative surgery is made somewhat difficult by the fact, to which attention has already been called, that in the first months of the war, conditions were listed as irreversible complications that later were recognized merely as indications for surgical attack. The recorded incidence of complications at this time was further affected by the tactical situation: Patients who were safely transportable could not be held in general hospitals for longer than 3 weeks. For these reasons, the incidence of complications in these first months of fighting in North Africa seems smaller than it actually was. The peak incidence of complications that required therapy was during the Sicilian and the early Italian campaigns. At this time, the incidence was 52 percent, as shown by an analysis of 870 thoracic wounds collected from seven general hospitals, four of which at times operated as thoracic centers. By the end of the war, the incidence had declined to 15 percent.

This highly favorable trend meant that, as the war progressed, more and more men with chest injuries were making uneventful recoveries from their wounds. Less and less major surgery was required in fixed hospitals because of the improved quality of forward surgery. Clarification of the indications for thoracotomy in forward hospitals (p. 200), improved methods of resuscitation, and the introduction of penicillin all played their part in the decrease of intrathoracic complications that required surgery in base hospitals. The improvement must, in the main, be credited to the so-called learning curve, already commented upon, which implied that both forward and base surgeons increased in experience and skill as the war progressed.

CHAPTER XIII

Reconditioning and Rehabilitation

Dwight E. Harken, M.D., B. Noland Carter, M.D., and Michael E. DeBakey, M.D.

GENERAL CONSIDERATIONS

Policies of hospitalization differ in civilian and military medical practice. A civilian is hospitalized for only part of the time that he is under medical treatment or observation. It is the rule rather than the exception for a surgical patient to be discharged from a civilian hospital early in the postoperative period to complete his convalescence at home. Moreover, he can return to work promptly, at least on a part-time basis, if physical endurance is not a prerequisite.

The military casualty who sustains a wound can be returned to duty promptly within the army area, and occasionally within the division area, if his wound is slight. For psychologic reasons, if for no other reasons, this is the wisest policy. If his wound is of any consequence, he must remain in some hospital until he is physically fit for duty or until he is separated from service after maximum benefits have been obtained from hospitalization. There is no assignment in the army, either on combat duty or limited service, for a soldier who can work only part of the time. This state of affairs necessarily prolongs the period of hospitalization for the wounded soldier.

These generalizations applied to all casualties in World War II. Thoracic casualties originally suffered under an additional handicap, the generally pessimistic outlook of the medical officers and others who cared for them. There was an unfortunate tendency to consider most of them as potential chest cripples, in the same category as the victims of empyema in World War I. As long as they were viewed from this standpoint, the results of treatment were less satisfactory than they should have been, for efforts at reconditioning and rehabilitation were lacking in vigor and enthusiasm if, indeed, any attempts at all were made. When it began to be evident that a wiser concept of chest wounds (p. 198), supplemented by new techniques of resuscitation, anesthesia, and surgery, was producing prompt and excellent results, a spirit of positive optimism began to pervade the thoracic services, involving patients as well as their surgeons and other attendants.

When it was practical, it was an excellent plan to maintain a separate medical thoracic section in close proximity to the surgical section in general

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hospitals on the base or in thoracic surgery centers. When bed space was available and interested internists were willing to assume the responsibility, the patient could be transferred to the medical section as soon as surgical care was no longer necessary, usually within 7 or 8 days. Nutritional deficiencies, anemia, and similar conditions were corrected under the care of the internist, and psychiatric and other care was provided as necessary.

The exercises to be described shortly were begun as soon as possible after operation, often within 24 hours. The program of early ambulation and exercise was correlated with early participation in work details. At the same time, ambulation was expanded into group exercises and then into hikes of increasing length. Bicycle exercises in bed were expanded, as soon as possible, into bicycle rides through the neighboring countryside. A full program of recreation was planned. The idea was to divorce the patient from his wounding and his surgical experience as promptly and completely as possible, so that he would be reconditioned mentally as well as physically for return to duty, preferably in the oversea theater.

Functional Studies

Facilities for bronchospirometric tests of thoracic casualties were not provided in the Mediterranean Theater of Operations, U.S. Army, and were not available in most hospitals in other theaters. Theoretically, these studies would have been desirable. They are, however, time-consuming, and it is doubtful that if facilities had been available, the time could have been taken to make them. They would have provided an objective criterion to indicate when a patient was ready for military duty, particularly if they had been performed serially. Most thoracic surgeons believed that clinical evaluation was quite as satisfactory in determining the activity level or the duty status.

At one chest center, serial fluoroscopic examination proved an efficient and fairly objective method of determining respiratory function. Examination of the normal chest showed that the parenchymal markings followed, in a general way, the ascent and descent of the diaphragm and, to a lesser degree, the upward and outward inspiratory lift of the ribs. The ribs moved in a pattern characteristically out of phase with the parenchymal markings (bronchial and vascular).

After injury, if progress was unsatisfactory and the chest became fused, fluoroscopic examination showed narrowing of the intercostal spaces, poor excursion of the costal cage, and immobility of the diaphragm, with a resulting reduction in respiratory efficiency. Even when such gross abnormalities were not present, pleural adhesions often greatly depressed parenchymal function. Often the only manifestation of the reduction was that the vascular and bronchial markings moved in phase with the movements of the costal cage instead of, as in the normal chest, out of phase with them.

Personnel

In whatever hospital chest casualties were treated, whether overseas or in the Zone of Interior, trained and interested personnel were essential to the success of the reconditioning program. Members of the Army Nurse Corps, male and female physiotherapists, and trained technicians were responsible for the constant attention to minute details and for the individual handling which these patients required. Their attitude was in large measure a reflection of the importance that medical officers who cared for the patients attached to the program.

Individual attention was mandatory, particularly after wounding, to assure the proper frame of mind on the part of the casualty. During wartime, the normal desire to recover completely and promptly was not always strong in the wounded soldier. Unless this negativistic tendency was counteracted promptly, the chest disability could easily become fixed, and the more prolonged the fixation, the more refractory it was to treatment. For this reason, individual attention by trained and enthusiastic personnel was necessary to institute and supervise chest exercises from the earliest feasible moment.

Some chest centers made a practice of using as assistants in the program certain carefully selected chest casualties who had recovered. It was a stimulating and encouraging object lesson for newly admitted patients to see another patient, with the same wounds they had suffered, looking fit and well and performing without difficulty the exercises they were being required to undertake.

Whatever the method, it was imperative that some member of the staff of the unit to which the casualty was admitted or transferred be aware of the importance of these exercises. It was the responsibility of whoever was in charge of the program to see that all patients were performing the exercises and that all were performing them correctly. It was also imperative that someone stand guard against the patient's fixation on his wound when he began to suffer from the dyspnea and tachycardia inevitable at the beginning of a rigorous training program. If specific remedial breathing exercises were not instituted and continued as indicated, the classical thoracic deformity would either occur or recur in serious chest wounds, and the casualty would be well on the way to becoming a chest cripple like his predecessors of World War I.

GENERAL POLICIES

Chest exercises were of two kinds:

1. The basic calisthenic program which eventually became part of the reconditioning of all wounded patients, regardless of the nature of their wounds (fig. 47), supplemented, for chest casualties, by special breathing exercises and exercises for the shoulder girdle.

2. The special exercises necessary to correct chest deformities that had already occurred.

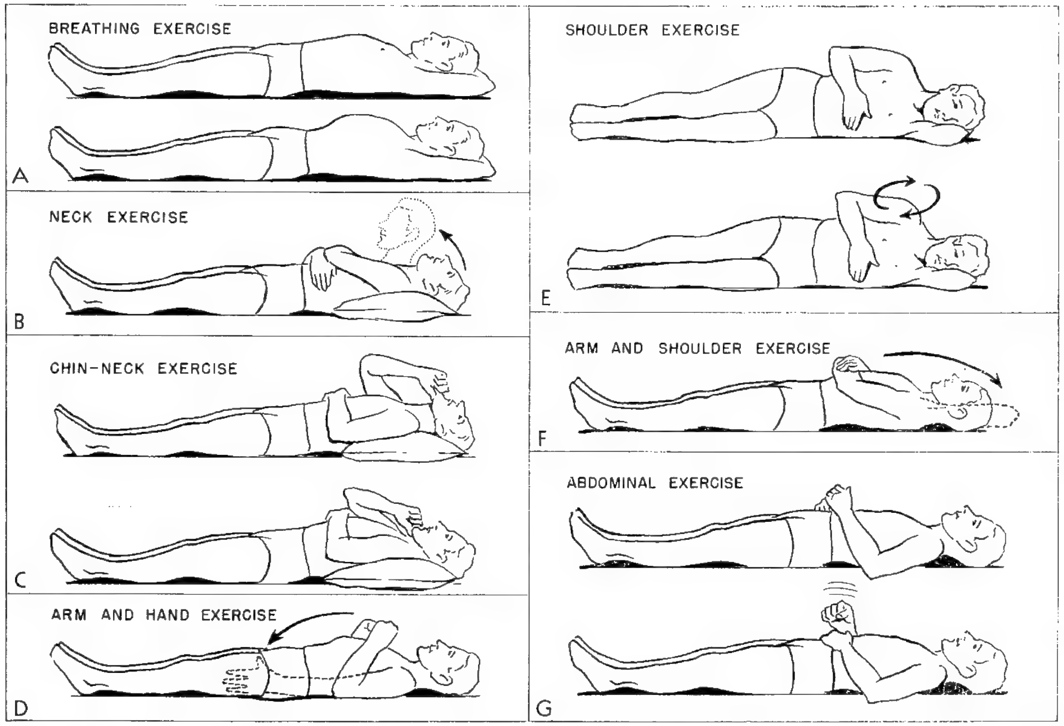


FIGURE 47.—Convalescent reconditioning exercises for bed patients. These exercises were devised in the European theater and published by the Office of the Chief Surgeon. They are presented as typical of the exercises generally used for this purpose. A. Breathing exercise. B. Neck exercise. C. Chin-neck exercise. D. Arm and hand exercise. E. Shoulder exercise. F. Arm and shoulder exercise. G. Abdominal exercise.

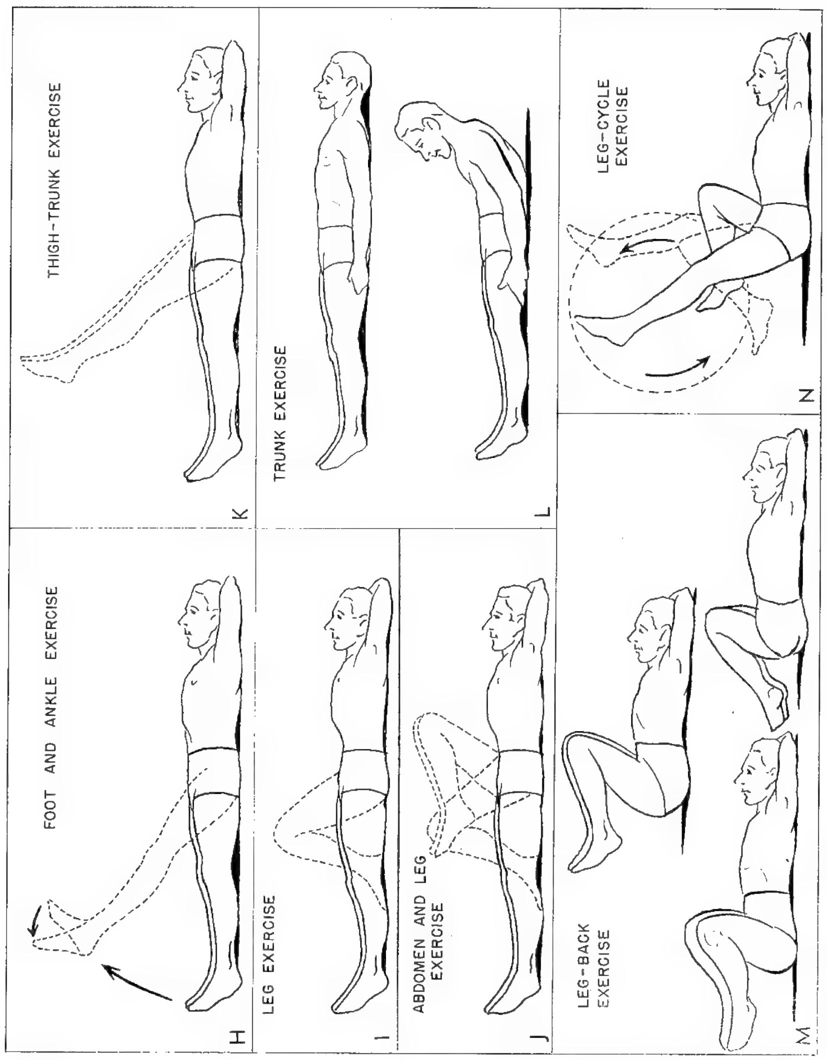


FIGURE 47.—Continued. H. Foot and ankle exercise. I. Leg exercise. J. Abdomen and leg exercise. K. Thigh-trunk exercise. L. Trunk exercise. M. Leg-back exercise. N. Leg-cycle exercise.

General (Preventive) Exercises

Whenever it was practical, it was a wise plan to train chest patients in breathing exercises and in special exercises for the shoulder girdle before operation. This eliminated the difficulty of instructing them in the required movements when postoperative discomfort might limit their cooperation.

As a rule, breathing exercises were started as soon after operation as the patient was oriented. In some chest centers, all patients, in addition to the special exercises required for their special injuries, practiced breathing exercises for 5 or 10 minutes of every hour during the day and until bedtime. The nurse and the wardmaster were responsible for seeing that the schedule was followed.

More vigorous exercises were usually possible by the second or third postoperative day. When this program was enforced, the respiratory excursion was frequently full and unimpaired by the time the soft-tissue wound was healed. Whether or not results were entirely satisfactory, the classical chest deformity was seldom part of the picture.

Corrective Exercises

Corrective chest exercises were designed to undo the sequelae of chest injuries in which deformity had been permitted to become established. Their rationale was as follows:

1. At the time of injury (operation), the chest wall becomes painful on motion, and the patient splints it voluntarily. Normally, both the voluntary and involuntary breathing mechanisms are symmetrical. When, however, the wounded side is splinted to avoid discomfort, it is divorced from the respiratory act. After a short time, the automatic neuromuscular mechanism is interrupted, and it frequently does not return spontaneously. In many injuries, immobilization that is first of voluntary, and then of neuromuscular, origin is mechanically reinforced and maintained by adhesions that have formed between the parietal and visceral pleura. The parietes and the lung are sometimes solidly incarcerated by the dense fibrous cortices.

When the pathologic process has progressed to this point, the classical chest deformity is likely to be present (appendix A, p. 341). The head is held laterally toward the injured side. The shoulder on the involved side slides downward and inward and moves medial to the vertical line from the anterior superior iliac spine. The chest wall is held in a position of full expiration. At the same time, the spine assumes a position of scoliosis and the pelvis is tilted toward the unaffected side.

When a casualty with a chest wound had been permitted to reach the state described, his condition could be corrected only by special exercises in which he received personal instruction.

Both in the European Theater of Operations, U.S. Army, and in the Zone of Interior, great stress was put upon elaborate special respiratory exercises.

The programs employed at the chest centers at the 160th General Hospital, Stowell Park, England, and at Baxter General Hospital, Spokane, Wash., were highly developed and extremely effective.

DEVELOPMENT OF PROGRAM, MEDITERRANEAN THEATER

In the Mediterranean theater, even in the early days of the fighting, the importance of deep breathing was emphasized to all patients. Practically all bed patients were able to participate in breathing exercises led by a corpsman especially trained in calling out orders.

Intelligent physiotherapy was also employed to great advantage in the early recovery phase. It was directed primarily toward early restoration of shoulder motion (fig. 48) and reestablishment of normal posture. It was found, however, that unless both medical officer and physiotherapist were alert to the progress of the individual patients, there was a tendency to continue this type of treatment far beyond the period of actual benefit. This overloaded the physical therapy department, needlessly prolonged hospitalization, and had an extremely bad psychologic effect on the soldier himself.

Shoulder girdle exercises were instituted in all patients with wounds or surgical incisions involving the muscles in this region. Patients without abdominal extension of their injuries also were trained in exercises tensing the abdominal wall. Flexing the leg and thigh muscles was added to the exercises after one or two instances of femoral thrombophlebitis had occurred.

With the single exception of those with cardiac wounds, patients who had had major chest surgery could be safely and comfortably out of bed within 24 hours after operation. Early ambulation had both physiologic and psychologic advantages. The wasting and atrophy of disuse were avoided. The dangers of pulmonary emboli were greatly reduced. The nutritional state often improved dramatically because the appetite improved and food intake increased. Empyema cavities which had remained stationary in size as long as the patients remained bedridden decreased in size when they became ambulatory.

Chest wounds were peculiarly well adapted to the program of early ambulation. With pain controlled by intercostal nerve block with procaine hydrochloride, the patient had no temptation to fight against movement or to practice protective splinting on the injured side (immobilizing it in total expiration and relaxing the accessory muscles of respiration).

Ambulatory patients were sent on daily walks, and were encouraged to participate in recreational activities. Some of them worked about the wards.

In the Mediterranean theater, blow bottles were found of little value, and no special attempts were made to teach the differential breathing exercises popular in the European theater. They were not thought necessary when a proper routine was followed immediately after surgery. In refractory cases, in which patients were received on the service with the shoulder girdle frozen, treatment consisted of heat, massage, and active and passive motion instituted under the direction of physiotherapists.

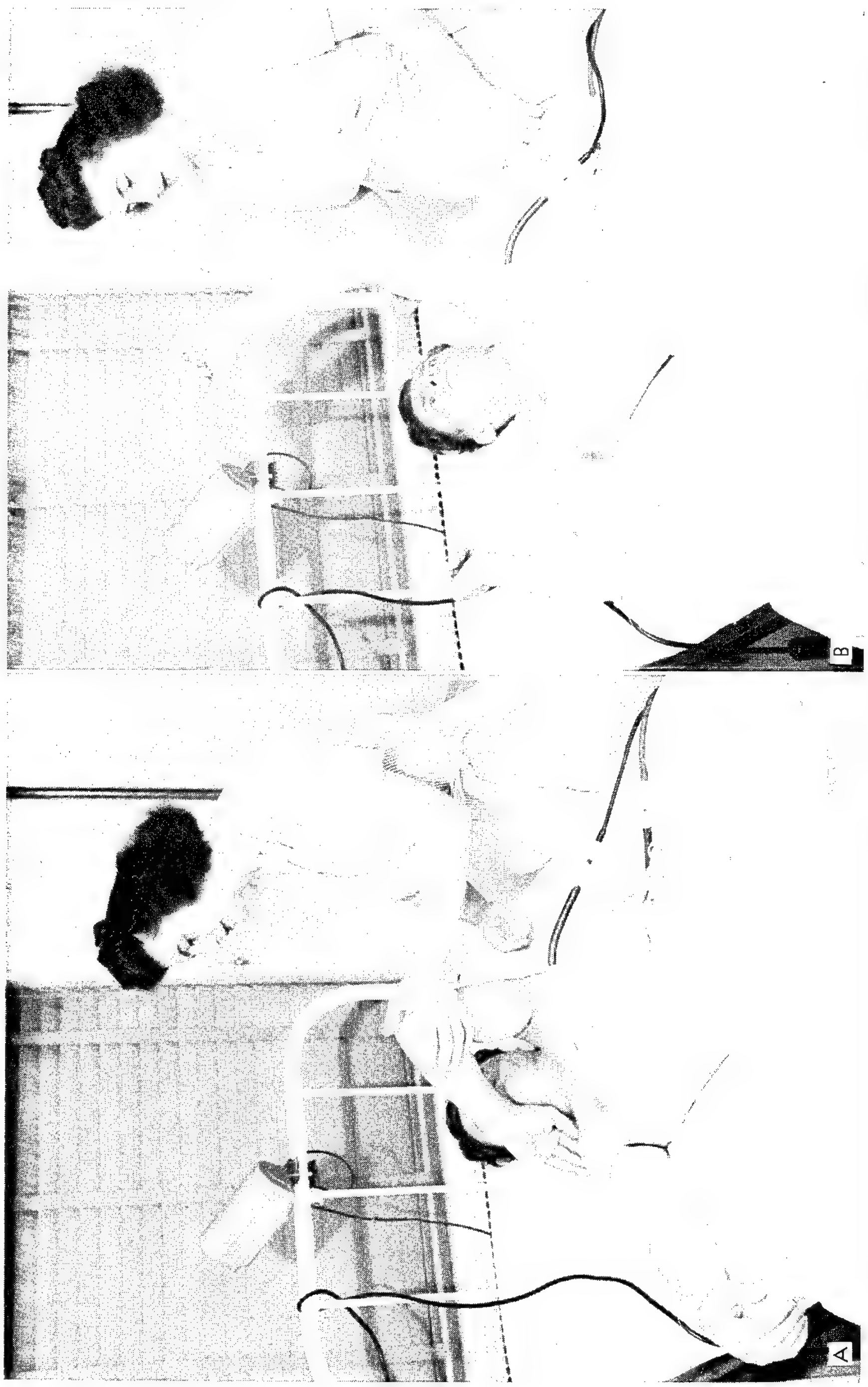


FIGURE 48.—Exercises to restore function of shoulder in chest casualties. A. Assisted horizontal adduction. B. Active flexion.

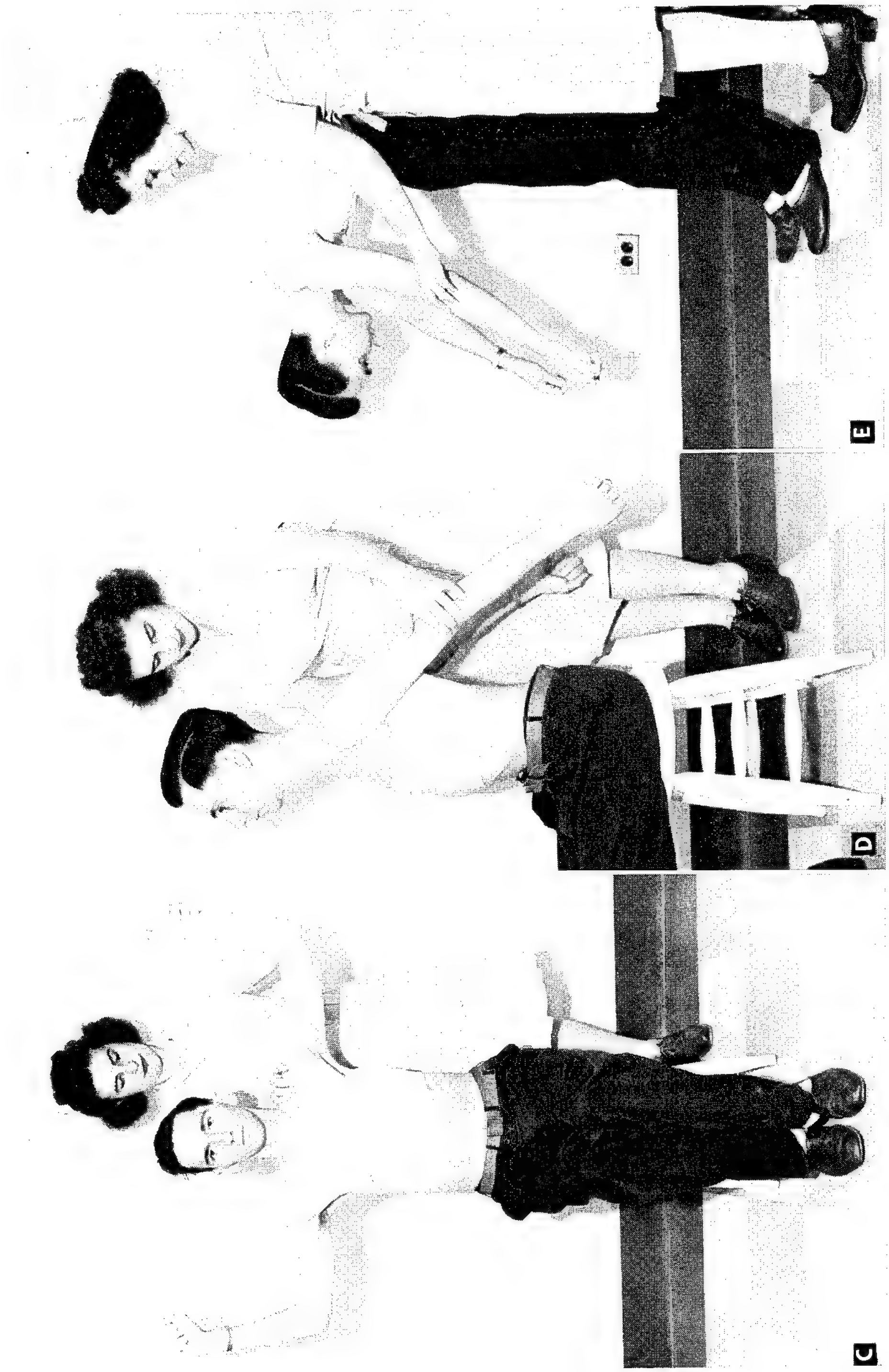


FIGURE 48.—Continued. C. Bilateral abduction with outward rotation. D. Extension. E. Circumduction.

THE PROGRAM IN THE EUROPEAN THEATER [1]

The reconditioning program employed at the 160th General Hospital chest center was under the direction of Maj. (later Lt. Col.) Dwight E. Harken, MC, and Capt. Joseph P. Lynch, MC. It was modified from the voluntary respiratory exercises which British thoracic surgeons had been employing for a number of years. The program at this center was chiefly based upon the routine employed by Mr. A. Tudor Edwards, under whom Major Harken had received part of his training (p. 115), and his physical therapy staff, particularly Miss Winifred Linton and Miss Jocelyn M. W. Reed (*1*).

Rationale of Exercises

These exercises were designed to teach the patient voluntary, unilateral, segmental, controlled breathing, on the theory that breathing is an activity that the human race has permitted to become almost entirely automatic, voluntary, and bilateral. By recapturing the ability to expand the affected side, it was possible to restore it to the functional level of the unaffected side. Calisthenics and the breathing exercises usually practiced, in the opinion of British chest surgeons, simply developed the unaffected side, to the further detriment of the injured side. They considered it neither practical nor desirable for the patient to undertake such activities until the lung on the affected side was fully expanded and the vital capacity correspondingly increased.

The purpose of these exercises was twofold:

1. To reestablish the lost neuromuscular arc from the motor cortex to the chest wall and diaphragm. Until this had been accomplished, it was futile to urge the patient to use the injured side of his chest.
2. To mobilize the chest wall and diaphragm, which were restricted locally by incarcerating cortices and adhesions. Accomplishment of this objective ultimately freed the pleura and allowed normal air and vascular exchange in the lung.

Procedure

As soon as possible after he reached the center, the patient was seen by a member of the thoracic reconditioning staff. Special records were made of his weight, chest expansion, function of thoracic cage, chest deformities, general status, and similar data. These records were used later for comparative purposes.

The patient was given a mimeographed sheet of instructions, which described the thoracic deformity, stated the principles of its correction, and detailed the manner of performing the specific remedial breathing exercises (appendix A, p. 341). At the same time, all of these matters were clearly explained to him in the simplest possible words. If he was ambulatory, the

[1] The reconditioning program at the 160th General Hospital chest center is presented as perhaps the most carefully worked out and supervised in the European theater.

nature of his deformity was demonstrated to him in the large mirror with which each ward was provided.

After the patient had been familiarized with his disability and deformity, he was shown how to lie correctly in bed. The tilted pelvis was returned to normal position, so that the weight was distributed equally on both buttocks. The shoulders were squared, and the head was shifted to the midline.

The next undertaking was the restoration of motor cortex control over the muscles of respiration. As already pointed out, man does not normally exercise voluntary control over the independent respiratory activity of separate sides of the chest, much less control particular segments within one hemithorax or the other. Yet, this was precisely what was necessary for the recovery of chest casualties, to prevent their becoming permanent chest cripples. The establishment of voluntary motor control over the injured hemithorax and its fused, sunken segments was the foundation of success in remedial breathing exercises. Equally important was voluntary motor control over the excursions of the diaphragm, in order to accomplish its remobilization.

The problem was essentially the education of the motor cortex, or, more properly, the education of the whole neuromuscular mechanism, in order to achieve voluntary control of areas that are not normally under the voluntary domain and that in the fused chest had also been dropped from the normal involuntary sphere.

Restoration of the mobility of the diaphragm was more difficult than restoration of the mobility of the chest wall, for three reasons:

1. It was impossible for the patient to see the results he was achieving.
2. The costophrenic adhesions, or, more correctly, the parietophrenic adhesions were often very dense and were slow to yield to the diaphragmatic pull.
3. The patient sometimes had great difficulty in comprehending the concept of abdominal breathing and more often than not would move the abdominal wall in a manner precisely opposite to the proper pattern.

The first step in the patient's reeducation in voluntary breathing was to make him find, or become aware of, the involved and immobile portion of his chest.[2] This was accomplished by having him place his hand over the affected area, institute gentle pressure, and exaggerate any existing respiratory excursions or initiate them if none were present. It usually required intense concentration for the patient to become conscious of specific areas of his chest.

The manner in which the pressure was delivered was also important. During the inspiratory effort, the pressure from the hand was just firm enough to establish an afferent pathway whereby he could become conscious of the area. During the expiratory phase, the pressure was much firmer, representing an exaggerated substitute for normal. When expiration was deepest, a gentle extra thrust, sharply released, would give the chest wall a spring or recoil that initiated the inspiratory phase of the act. Most often, it was this recoil that

[2] Illustrations for these exercises are in the material given to each patient (appendix A, p. 341).

the patient picked up and continued in his conscious effort to move the lagging area of the chest wall.

The key to the solution of problems connected with the diaphragm was to explain to the patient that on inspiration the chest wall increases the volume of the thoracic cavity, and therefore of the lungs, by opening like bellows, while the floor of the thoracic cavity (that is, the diaphragm) similarly increases the thoracic volume by dropping downward like a piston. After many trials, it was found that the comparison with a piston was the most effective description. When it was used, the patients quickly realized that the abdominal muscles must relax and be forced out by the descending piston and that, conversely, these muscles could force the piston upward into the thoracic cavity if they were contracted and the abdomen was pushed in. Progress in diaphragmatic breathing could best be assessed by fluoroscopic examination at 5-day intervals.

THE PROGRAM IN THE ZONE OF INTERIOR

Development of Program

At the Baxter General Hospital chest center, the program of reconditioning of thoracic casualties was developed to meet a specific need.[3] Many patients were admitted to the hospital who were in good condition after adequate and appropriate medical and surgical treatment overseas. Some patients, however, were found to have a persistent disability, which took the form of a constant complaint of inordinate dyspnea upon even moderate exertion. They simply had to drop out of whatever activity they were engaged in, sit down, and puff.

Physical examination of these patients showed that the side of the chest involved in the previous injury (or occasionally the previous disease) was restricted in its movement or fixed in the position of expiration. The ribs were in close approximation in the dependent position, and the diaphragm was elevated. On fluoroscopic examination, there was little movement of the affected rib cage or the diaphragm, even during an episode of dyspnea.

The explanation of these findings was that in the course of prolonged bed rest after wounding (or illness), with voluntary or involuntary limitation of thoracic motion on the affected side, a number of pathologic changes had occurred. The muscles of respiration had become markedly atrophic. Fibrous thickening had developed in the parietal pleura, intrathoracic fascia, and intercostal structures, with considerable fibrous obliteration of the pleural space. The diaphragm on the affected side had become seriously involved in the process, and as a result, the respiratory muscles motivating the mechanism of breathing had lost their strength. In addition to this handicap, these muscles had another burden imposed upon them, that of moving the ribs and the diaphragm (the bellows of the respiratory apparatus), which were fixed by fibrous adhesions.

[3] The reconditioning program at the Baxter General Hospital chest center is presented as perhaps the most carefully worked out and supervised in the Zone of Interior.

Casual inspection of these patients, and even careful study of their roentgenograms, gave no hint of the severity of their disability. That became apparent only when the severe dyspnea produced by moderate exertion was observed. Apparently, the increased metabolism caused by exercise resulted in an accumulation of carbon dioxide in sufficient amounts to activate the respiratory center. The oxygen levels remained adequate, as indicated by the absence of cyanosis and the normal coloration of the peripheral circulating blood.

A number of studies would have been desirable, including determination of the vital capacity; determination of the oxygen and carbon dioxide blood levels; selective spirometry of the tracheobronchial tree; and studies of samples of tidal air for comparison of the relative nitrogen, oxygen, and carbon dioxide levels of the affected and unaffected hemithoraces. Facilities for these investigations were not available.

In the absence of this fundamental information, the best plan seemed to be to devise a program of exercises which, by specific direction toward that end, would rapidly redevelop the muscles of respiration without imposing a total physical contribution upon the entire body. It also seemed important that these exercises be so planned that they could be continued for long periods without the development of dyspnea, which would discourage further activity; it had been observed that the breathlessness or sense of breathlessness associated with the false dyspnea of carbon dioxide accumulation discouraged further activity and thus helped to maintain the process which was causing it.

The program at Baxter General Hospital was under the general direction of Maj. Thomas B. Wiper, MC, assisted by Maj. James T. Lang, CAC, Capt. Leslie T. Wood, Inf., Capt. David Blair McClosky, AC, and T. Sgt. Renold Cook (*2*). An important collaborator was Captain McClosky, a former concert singer, who had suffered a loss of respiratory capacity and experienced a sense of breathlessness after surgical treatment of postpneumonic empyema.

A letter of greeting from the commanding officer of Baxter General Hospital to all thoracic casualties (appendix B, p. 345) made them cognizant at once of the importance attached to the exercise program.

Indications for Exercises

The exercises that were part of the reconditioning program for chest casualties were taught to the following groups of patients:

1. Those with dyspnea on exertion, as just described.

2. Those with stabilized empyema in which there was delay in reexpansion of the lung after adequate drainage.

3. Those with stabilized lung abscesses in which there was delayed obliteration of the space left after adequate drainage.

4. Those with small residual hemothoraces in which the space did not provide sufficient room for surgical decortication.

5. Those with structural deformities of the thoracic cage resulting from multiple rib fractures caused by crushing injuries.

6. Those to be submitted to elective thoracotomy, so that they would be prepared to begin these remedial exercises immediately after recovery from anesthesia. This group of patients was transferred to the convalescent ward as soon as possible, so that they might take part in the additional exercises instituted for all casualties who had advanced to this status.

Routine of Exercises

The exercises employed at this chest center were devised to strengthen all the muscles of respiration and to mobilize the ribs, lung, adherent pleural surfaces, and diaphragm. Mobilization of these fixed structures was accomplished by the pull of selective muscle groups upon the rib cage and by exercises which utilized the principle of Valsalva's maneuver.

The exercises were graded and phased as follows:

1. For the first 8 to 10 days after operation, exercises consisted of deep breathing; active movements of abduction, adduction, flexion, and extension of the arms; and active abduction and adduction of the scapula (figs. 49 and 50). The physiotherapist, in addition to supervising these active movements of the respiratory muscles and muscles of the shoulder girdle, which were designed to prevent atrophy and fixation, also worked to improve the posture of the patient in bed. Selected patients also received diathermy, radiant heat, and massage according to their special needs.

It was found at this center that the immediate postoperative reconditioning of chest casualties could be most satisfactorily conducted under the direction of female physiotherapists who had been indoctrinated with the basic philosophy of the reconditioning program and who understood the anatomy of the muscles which participate in the respiratory act.

At the end of this period, the patients were reclassified and moved to a preconvalescent ward. Here they came under the direction of male instructors in the physical reconditioning section.

2. Between the 10th and 15th days after operation, 11 basic thoracic exercises were conducted twice daily, for 15 minutes at a time (*figs.* 51–61).

3. Between the 15th and 20th days after operation, the exercise periods were increased to 20 minutes twice daily, and each exercise was repeated 8 times.

4. Between the 20th and 23d days after operation, the exercises were conducted for 25 minutes twice daily and "Tarzan" exercises were added to the list (fig. 62).

5. Between the 23d and 26th days after operation, the exercises listed were conducted for 30 minutes twice daily.

6. Between the 26th and 30th days after operation, the exercises were carried out for 40 minutes twice daily, and supplementary exercises (figs. 63, 64, and 65) were added for warmup purposes. Other exercises, including woodchopping and swimming, were added at the discretion of the instructor. All exercises were carried out with emphasis on deep breathing.

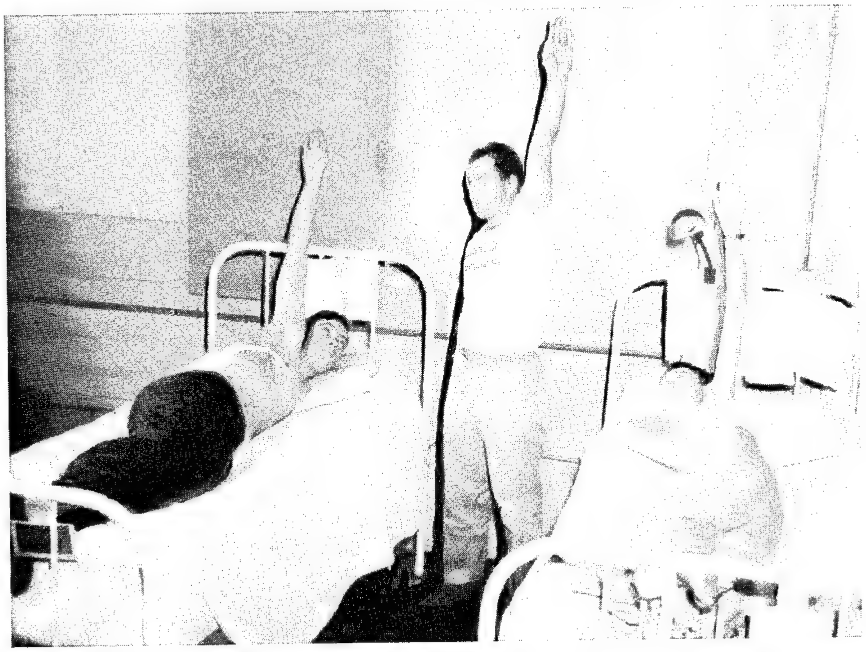
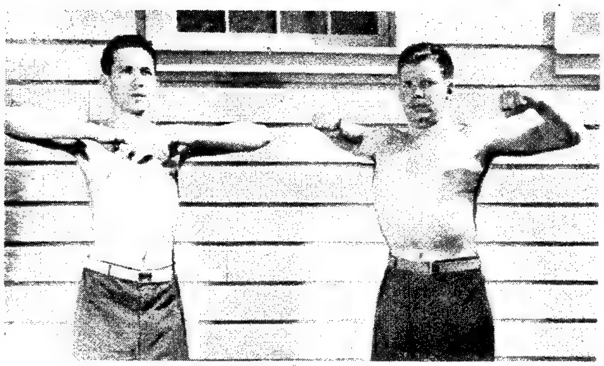


FIGURE 49.—Individually prescribed exercises for early postoperative period, Baxter General Hospital chest center (2).

FIGURE 50.—Mild thoracic exercises 7–14 days after operation (2).

I • BREAKING CHAINS



Tense hands and arms . . . inhale vigorously.

POSITION

Body erect, feet comfortably spread.

Elbows extended horizontally at side.

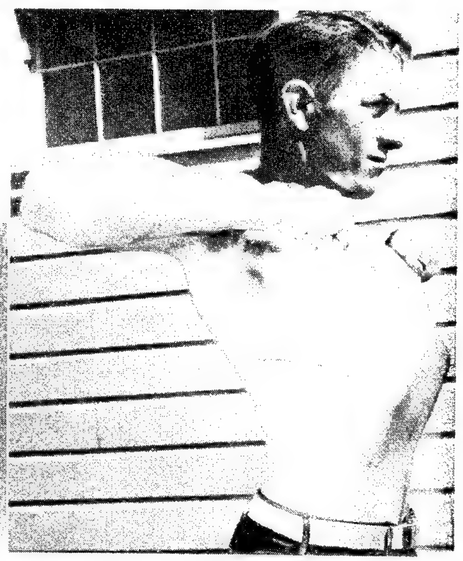
Hands loosely clenched, palms down in front of shoulders.

MOVEMENT

1. Pull elbows back hard as though trying to break a chain held between hands. INHALING DEEPLY AND RAISING DIAPHRAGM
2. Relax to starting position and exhale vigorously.
3. Repeat with 8 to 10 repetitions of 4 counts.

Cadence—slow

Draw arms and shoulders backwards . . . elevate the chest.



Recover to starting position and exhale vigorously . . . puff!

PURPOSE

1. Increases anterior posterior diameter of chest.
2. Increases transverse diameter of chest.
3. Produces rotation and elevation of the ribs.
4. Expands the lungs.
5. Produces movement of pleural surfaces.

FIGURE 51.—Basic thoracic exercises. 1. Breaking chains (2).

• ELBOW EXERCISE 2

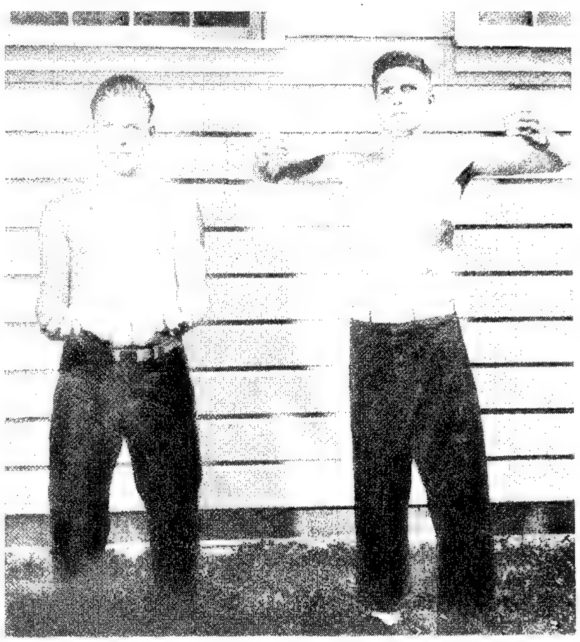
POSITION

Arms at sides, bent at the elbows with forearms and palms in supinating position, fingers loosely clenched.

The shoulders and neck are relaxed.

To begin the exercise, the weight of the body is slumped on one foot.

WEIGHT FORWARD



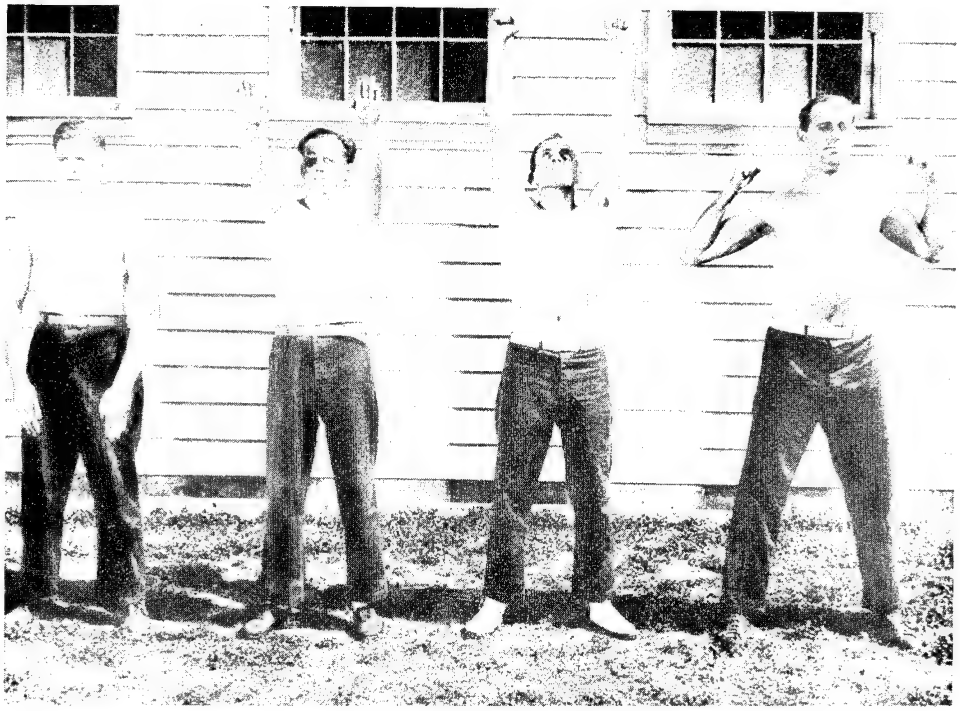
Elbows relaxed and at the sides . . . inhale deeply . . . elevate chest.

PURPOSE

1. Increases transverse diameter of chest.
2. Produces rotation and elevation of the ribs.
3. Expands the lungs.
4. Produces movement of pleural surfaces.
5. Mobilizes and strengthens shoulder muscles.

Neck and shoulder muscles relaxed . . . diaphragm drawn in . . . ribs elevated.

FIGURE 52.—Basic thoracic exercises. 2. Elbow exercise (2).

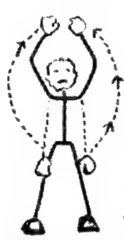


Inhale and reach for the sky . . tense hands and arms and force downward.

• ARM EXERCISE 3

POSITION

Body erect, feet comfortably spread.
Arms in front, palms resting on thighs.



INHALE

MOVEMENT

1. As patient inhales, the arms slowly move forward and up over the head. (As the arms reach the overhead position, the breath should be fully drawn in and the lower abdominal muscles fairly flat.)
2. While the breath is being held, simultaneously, the hands are clenched, elbows bent, and the arms are drawn down tightly against the sides of the chest.
3. The shoulders, in the meantime, are pressed down and slightly back.
4. At the same time the muscles of the upper abdominal area are forcibly drawn in.
5. The patient retains the air as long as possible while doing a series of pumping movements with the shoulders and arms.

(This can be supplemented by rotating arms and shoulders forward and backward, alternately elevating and compressing the chest.)

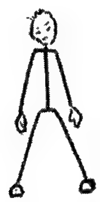
Note: Be sure while drawing the arms down that they are neither front nor back, but directly at the sides.

PURPOSE

1. Increases anterior posterior diameter of chest.
2. Increases transverse diameter of chest.
3. Produces rotation and elevation of the ribs.
4. Expands the lungs.
5. Produces movement of pleural surfaces.
6. Mobilizes and strengthens shouldes muscles.

EXHALE

FIGURE 53.—Basic thoracic exercises. 3. Arm exercise (2).



4 • RIB STRETCHER

POSITION

Body erect, feet comfortably spread.

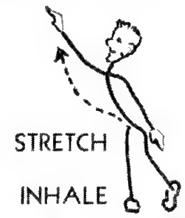
MOVEMENT

1. During deep inhalation, the arm ON THE INJURED SIDE of the body is raised slowly sideward and upward with the palm of the hand out. Head and eyes follow the hand upward.
2. While raising the arm to the outward position, rise up on the toes of foot on normal side. IT IS IMPORTANT that hip on injured side be kept in line with the foot on that side.
3. When the arm has reached the ultimate position and breath is in, this position is held with arm and fingers straining upward and outward, simultaneously, the injured side of the chest is made to follow the hand.

PURPOSE

1. Mobilizes ribs and intercostal substance on side of injury.
2. Increases intercostal interval by rotation and elevation of ribs.
3. Increases chest capacity of damaged hemithorax.
4. Mobilizes and strengthens shoulder muscles.
5. Produces movement of adherent pleura.

"Watch the chest follow the hand!"



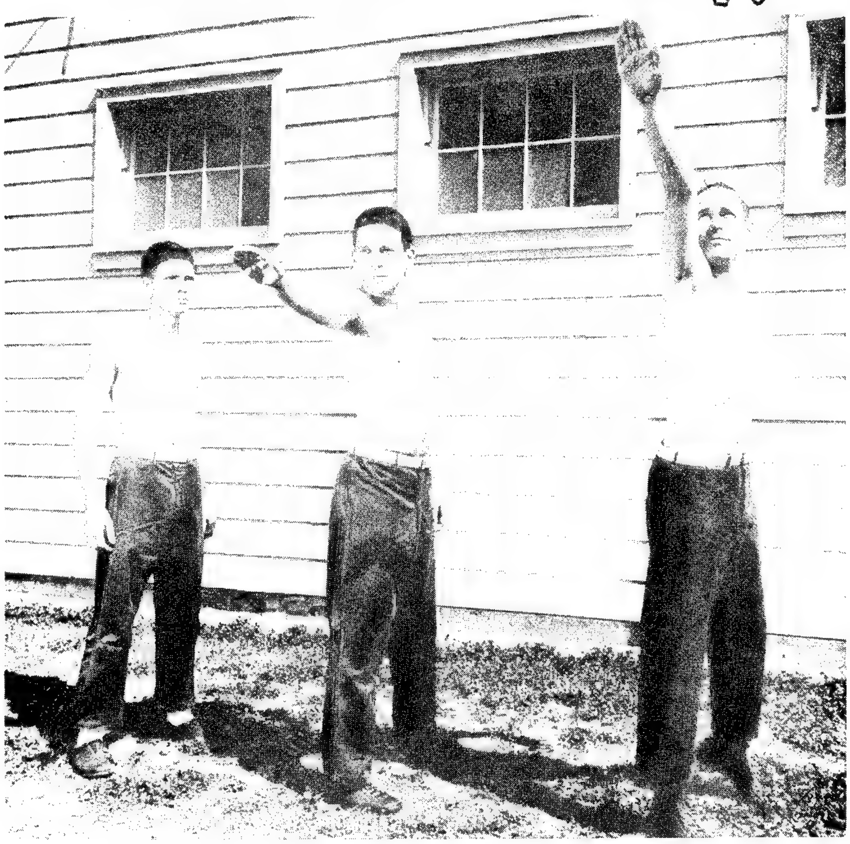
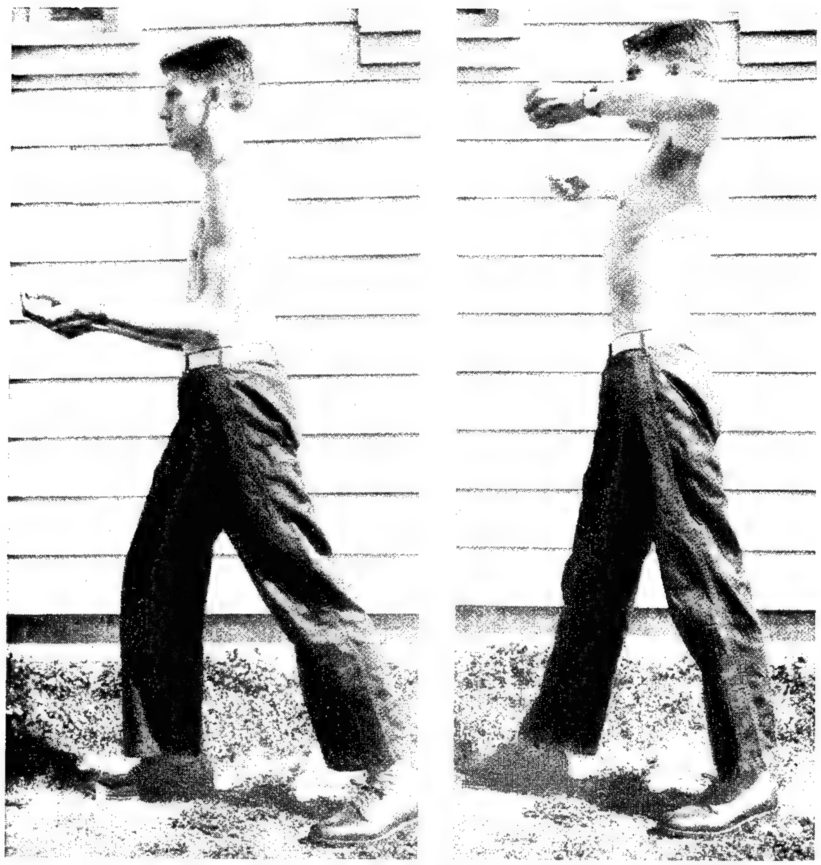


FIGURE 54.—Basic thoracic exercises. 4. Rib stretcher (2).



Weight on forward foot . . . inhale . . . let ribs follow the elbows out.

INHALE

MOVEMENT

1. INHALE DEEPLY, at the same time rock backward from original position to an erect position, simultaneously the muscles of the lower region of the abdomen are drawn up and the elbows and hands are moved directly out from the sides, putting tension upon the imaginary string pulling the ribs outward.
2. The patient then EXHALES VIGOROUSLY and recovers to starting position.
3. Patient must imagine that attached to his elbows is a string which in turn is attached to the ribs.

Note: It is important that the shoulders do not rise with this exercise, nor should there be undue tension of the neck muscles.

EXHALE

FIGURE 54.—Continued

This is a slight variation of exercise No. 4 but is much more vigorous.

• AGAINST THE WALL 5

POSITION

Body erect, feet comfortably spread.
Hand on normal side against the wall at an even weight with shoulder.
Foot on normal side about 18 inches from the wall.

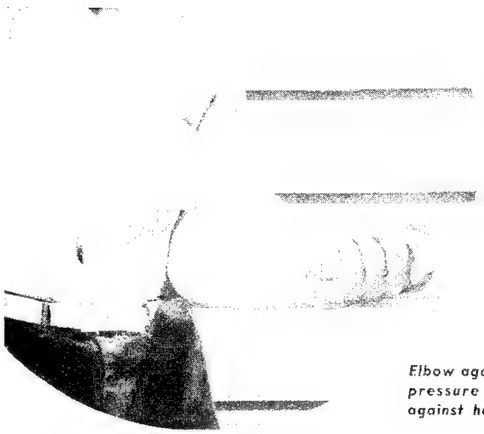
MOVEMENT

1. Initial movement is same as in Exercise No. 4.
2. The hand on the wall presses against the wall as the arm rises and as the breath comes in. Counter pressure (toward the wall) is applied with the leg on the injured side.
   Note: This motion will tend to take all the weight off the foot nearest the wall.

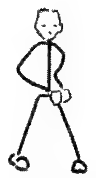
PURPOSE

1. Mobilizes ribs and intercostal substance on side of injury.
2. Increases intercostal interval by rotation and elevation of ribs.
3. Increases chest capacity of damaged hemithorax.
4. Mobilizes and strengthens shoulder muscles.
5. Produces movement of adherent pleura.

FIGURE 55.—Basic thoracic exercises. 5. Against the wall (2).



6 • CLASPED HANDS



POSITION

Body erect, feet comfortably spread.

Hands clasped.

Elbow of arm on normal side against the side of lower rib.

ELBOW PRESSURE

Elbow against normal side . . . pressure of opposite hand against hand on normal side.

MOVEMENT

1. As a full breath is taken, pressure is made by the elbow against the ribs on the healthy side.
2. The shoulder of the affected side is bent toward the front and the opposite shoulder.
3. Pressure of breath should be felt in the back and sides of affected ribs. Concentration must be made there and assisting pressure applied.

Note: It is important to keep both feet firmly on floor, knees straight and hips in fixed position to avoid rotation of lower extremities.

PURPOSE

1. Mobilizes ribs and intercostal substance on side of injury.
2. Increases intercostal interval by rotation and elevation of ribs.
3. Increases chest capacity of damaged hemithorax.
4. Mobilizes and strengthens shoulder muscles.
5. Produces movement of adherent pleura.

SIDE TWIST

Start with hand comfortably in front . . . twisting injured side and shoulder to the opposite side.

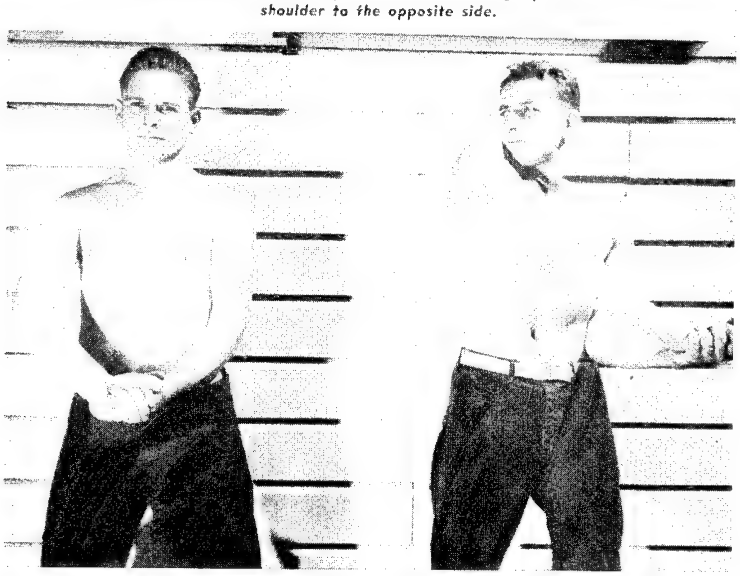


FIGURE 56.—Basic thoracic exercises. 6. Clasped hands (2).

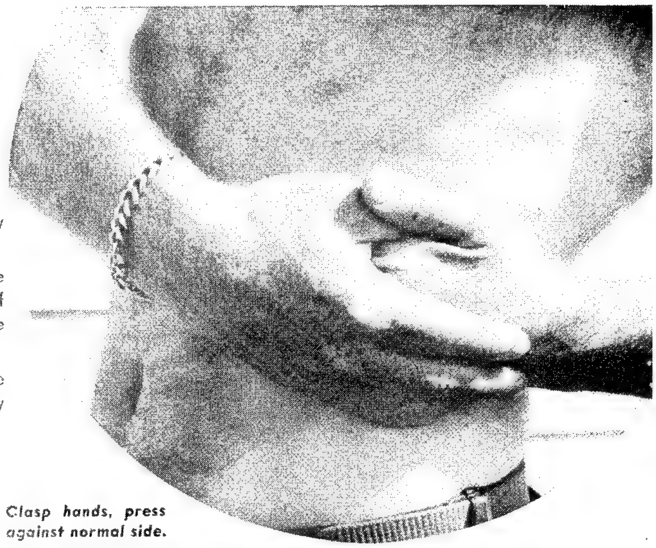
• HAND ON CHEST 7

POSITION

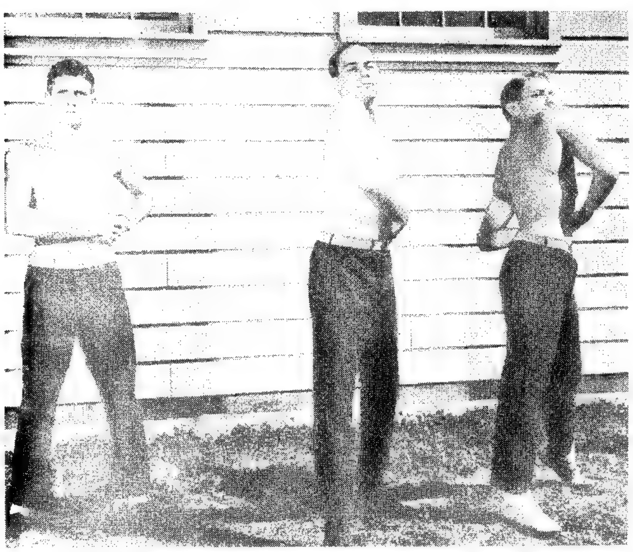
Body erect, feet comfortably spread.

Hands interlocked, palm of the hand on the normal side of the chest pressed against the side of the lower ribs.

Elbow of the affected side should be held slightly away from the chest.



Clasp hands, press against normal side.



Inhale . . . step forward . . . twist injured side forward and upward.

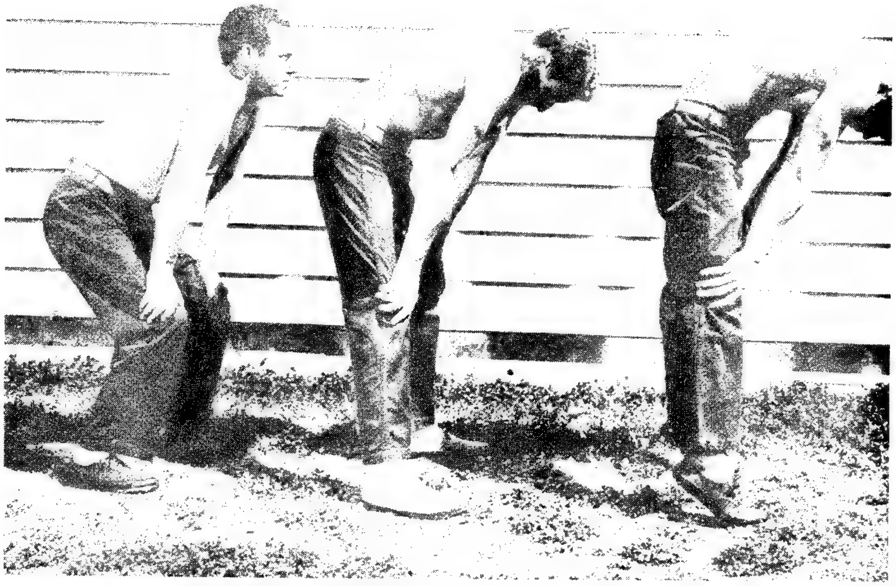
MOVEMENT

1. Inhale deeply, apply more pressure to the hands, place the foot on the injured side one full step directly forward, at the same time twisting shoulder forward and toward the opposite side.
2. EXHALE VIGOROUSLY and relax to starting position.

PURPOSE

1. Mobilizes ribs and intercostal substance on side of injury.
2. Increases intercostal interval by rotation and elevation of ribs.
3. Increases chest capacity of damaged hemithorax.
4. Mobilizes and strengthens shoulder muscles.
5. Produces movement of adherent pleura.

FIGURE 57.—Basic thoracic exercises. 7. Hand on chest (2).



Inhale from crouch position . . . rock on toes.

8 • HAND ON KNEE

POSITION

Feet well spread, hands on knees.
Body in football crouch.

INHALE

MOVEMENT

1. Inhale deeply, press hands against knees and rock forward on the balls of the feet.

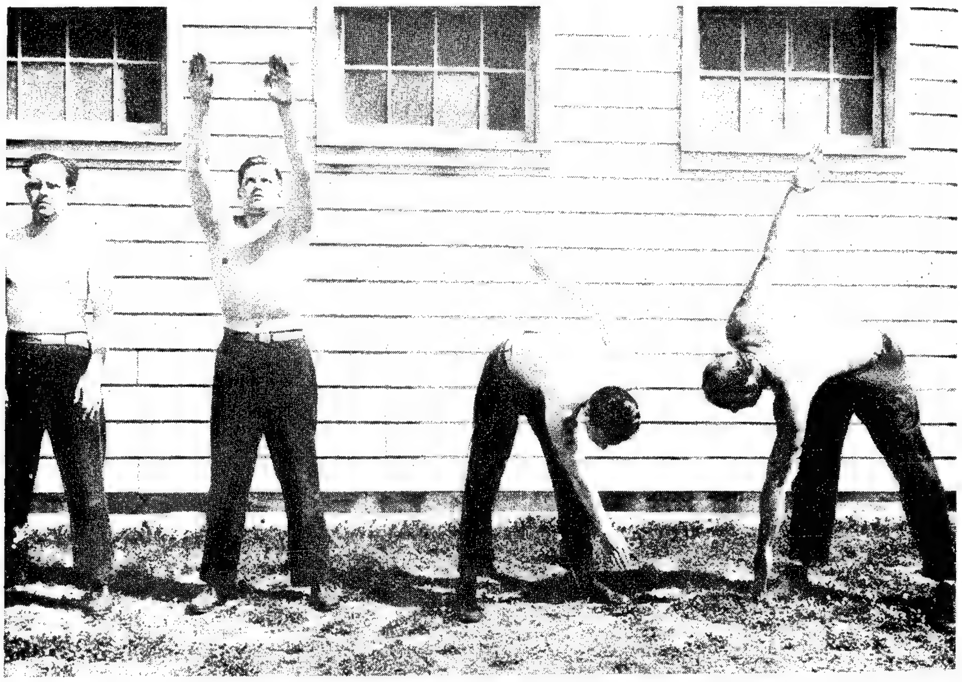
2. Flatten the stomach muscles and concentrate the breath entirely in the posterior portion of the lungs and upper back.
3. Lower head and neck and strive to hump the back as much as possible. This entire exercise is done in one movement.
4. Exhale and relax to starting position.

PURPOSE

To force the air into the posterior portions of the lung by humping the back and tensing the abdominal muscles.

ON TOES

Figure 58.—Basic thoracic exercises. 8. Hand on knee (2).



• HAND ON FOOT 9

Stretch out and up . . . fill the lungs . . . bob to the left foot and then to the right . . . while holding breath.

POSITION

Body erect, feet in side-straddle.

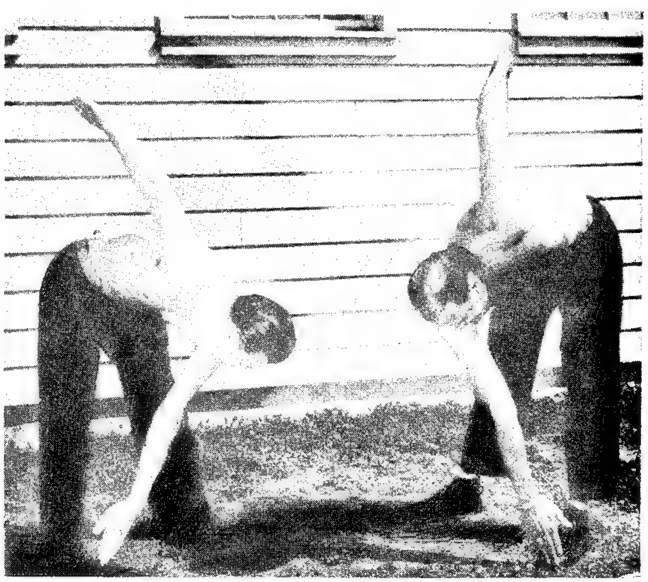


FIGURE 59.—Basic thoracic exercises. 9. Hand on foot (2).

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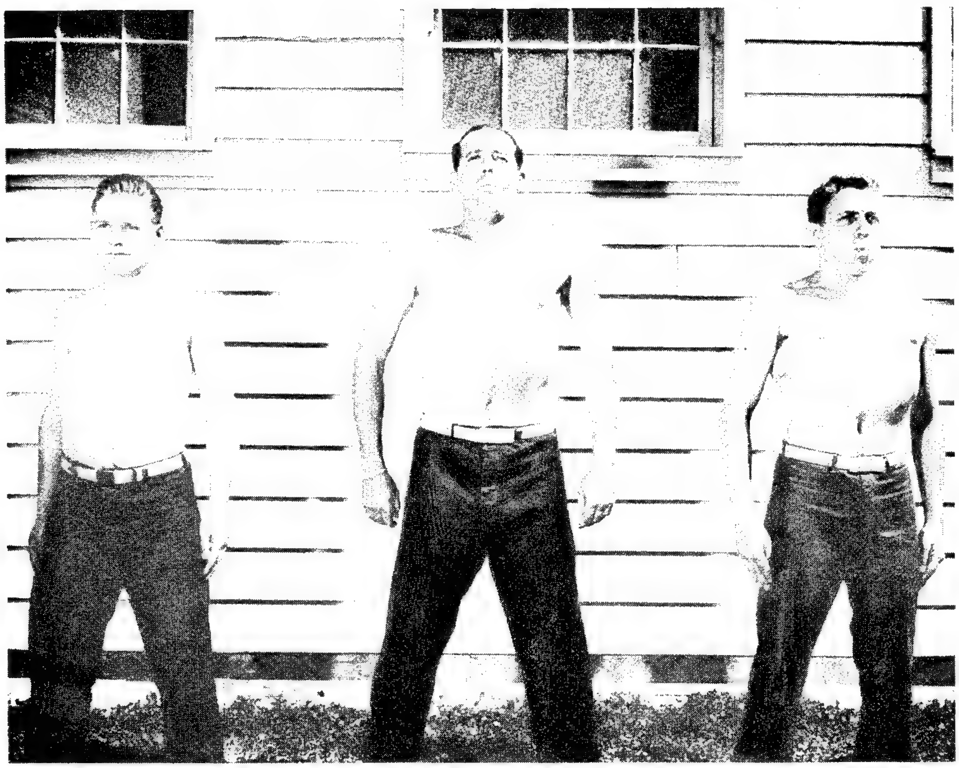


Inhale vigorously . . . keep chest expanded . . . then inhale and exhale slowly using the diaphragm only.

• FULL CHEST 10

POSITION

Body erect, feet comfortably spread.

MOVEMENT

1. Inhale deeply.
2. Expand chest as far as possible.
3. Exhale at first slowly and then more rapidly as technique for control of the diaphragm and abdominal muscles is learned.

Note: It is important to keep the chest expanded and the ribs raised throughout this exercise. Avoid letting chest drop as in normal breathing.

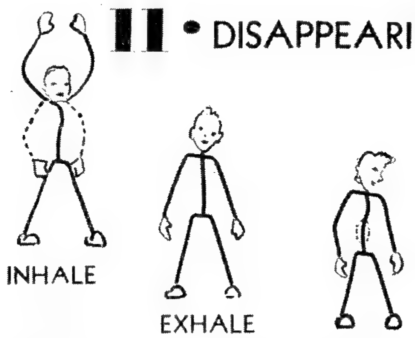
PURPOSE

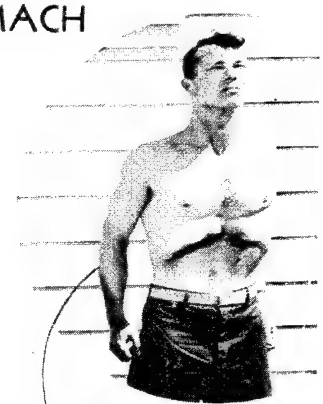
1. Increases anterior, posterior and transverse diameter of the chest.
2. Strengthens abdominal and diaphragmatic muscles.
3. Particularly useful in mobilizing an elevated, adherent diaphragm, previously fixed to chest wall by disease or injury.

DIAPHRAGM BREATHING
DEPRESS AND RELAX

FIGURE 60.—Basic thoracic exercises. 10. Full chest (2).

11 • DISAPPEARING STOMACH





Stimulates normal function of the diaphragm . . increases chest capacity.

POSITION

Body erect, feet comfortably spread.

DIAPHRAGM DRAWN IN AND OUT ALTERNATELY

MOVEMENT

1. Inhale deeply raising arms forward to the overhead position.
2. Exhale vigorously at the same time lowering arms forward to starting position. Bend body forward from waist, completely deflating lungs.
3. Close valve in throat, resume erect position at the same time drawing diaphragm in as far as possible.
4. Alternately draw in and relax diaphragm. This exercise causes great action in abdominal and diaphragmatic sections.

PURPOSE

1. Strengthens abdominal and diaphragmatic musculature.
2. Mobilizes adherent diaphragm.
3. Produces increased thoracic space by elevation and rotation of ribs.
4. Strengthens all respiratory muscles.
5. Mobilizes and strengthens shoulder muscles.

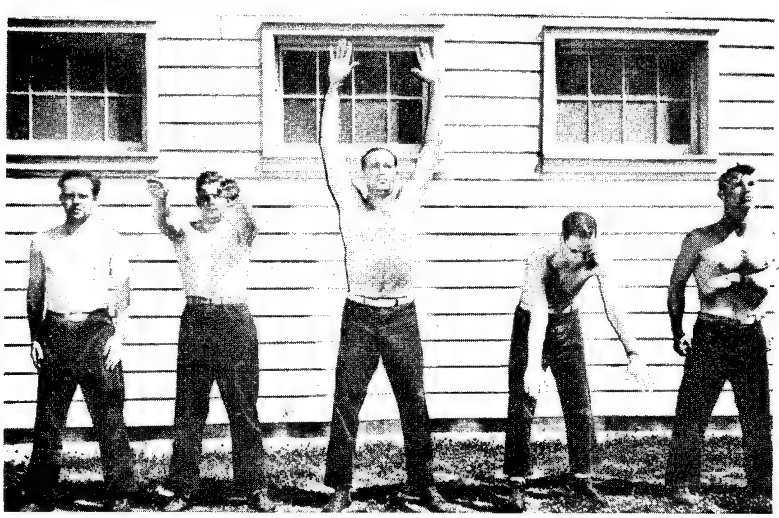
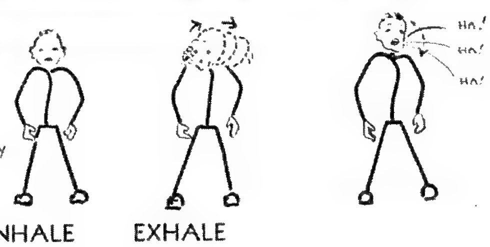


FIGURE 61.—Basic thoracic exercises. 11. Disappearing stomach (2).

• TARZAN 12



POSITION

Body erect, feet slightly spread.

MOVEMENT

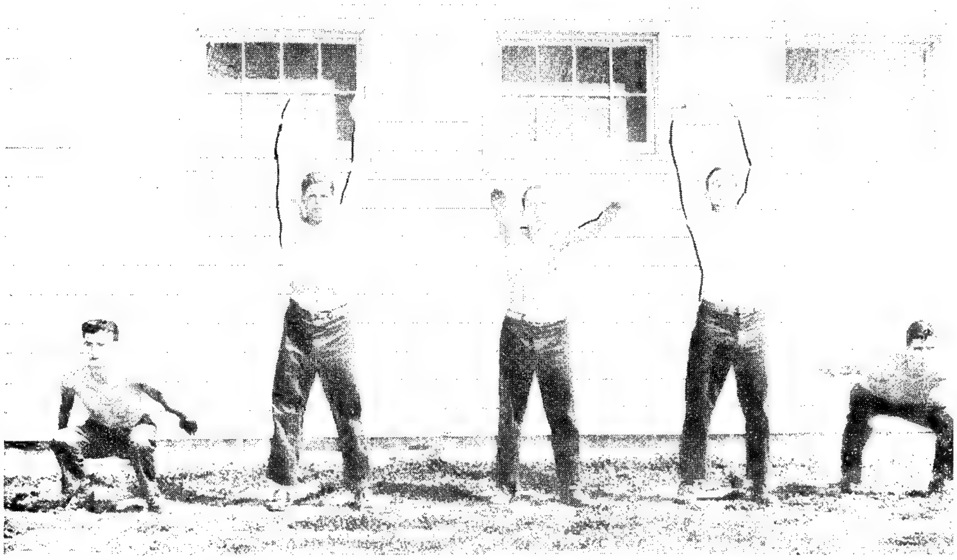
1. Inhale deeply, relax neck muscles, allow mouth to open.
2. With forceful use of diaphragm, yell on the vowel "A" keeping the chest raised, but using only a violent lift of the muscles of the upper abdominal area to give the sound its impetus.

PURPOSE

1. Strengthens diaphragm.
2. Mobilizes adherent diaphragm.
3. Produces increased thoracic space.
4. Teaches controlled respiration.

FIGURE 62.—Basic thoracic exercises. 12. Tarzan exercise (2).

SUPPLEMENTARY EXERCISES



• HIGH JUMPER

POSITION

Feet in side straddle position, knees well bent.

Body in crouched position.

Arms extended, palms up.

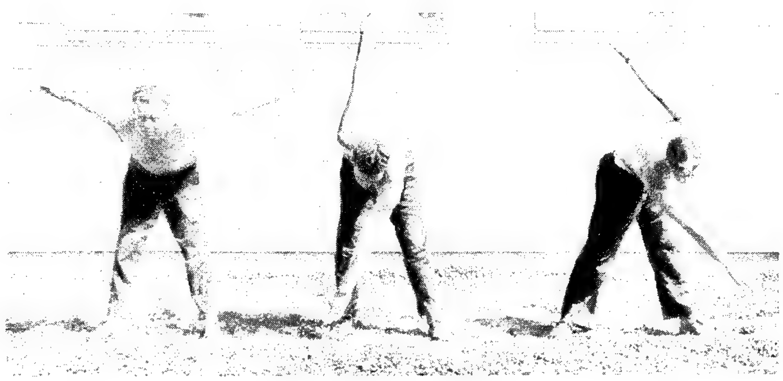
MOVEMENT

1. Inhale deeply, extend body to erect position at the same time extend arms well overhead.
2. Exhale and forcefully flex arms to position parallel with shoulders.
3. Inhale deeply and assume completed position of step No. One.
4. Repeat step No. Two.
5. Repeat step No. One.
6. Exhale vigorously and relax to starting position.

PURPOSE

1. Strengthens and mobilizes shoulder muscles.
2. Increases chest capacity by rotation and elevation of ribs.
3. Forcibly reduce chest capacity and thereby
4. Produce movement of pleural surfaces and mobilization of diaphragm.

FIGURE 63.—Supplementary exercises. High jumper (2).



• SHOULDER SWING

POSITION

Feet side straddle, knees straight.
Hips in a fixed position.
Body bent forward at waist, arms raised sideward.

MOVEMENT

1. Swing left arm and shoulder vigorously as far to the right as possible.
2. Alternately swing right arm and shoulder to the left in like manner.
   Two movements with each arm constitute one repetition.

   Note: It is important to keep knees and hips in fixed position to create a twisting motion of the thoracic cage as well as to warm up the shoulder and arm muscles.

PURPOSE

1. Strengthens and mobilizes shoulder muscles.
2. Mobilizes ribs by elevation and rotation pull exerted by shoulder muscles.

POSITION

Erect, feet together.
Arms sideward, palms up.

MOVEMENT

1. Inhale, raise left leg forward with knee straight until foot is approximately the height of the shoulder, and at the same time swing arms forward, touching foot with hands. The right knee may be somewhat bent. During this kicking movement exhale vigorously.
2. Inhale and recover to starting position.
3. Repeat count one with right foot.
4. Recover to starting position.

PURPOSE

1. To increase chest capacity by mobilizing ribs.
2. To mobilize diaphragm by compression from increased intra abdominal pressure.

• FRONT KICK

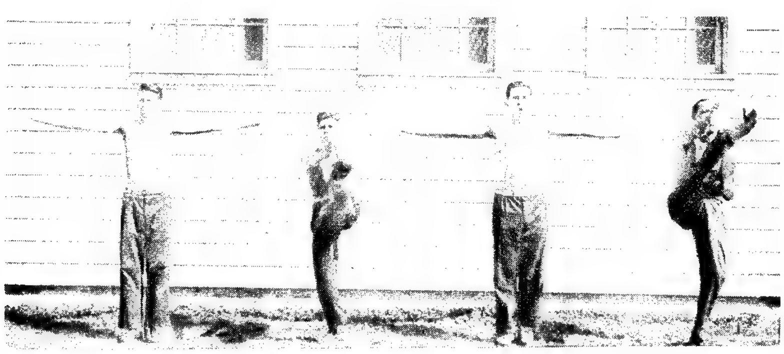
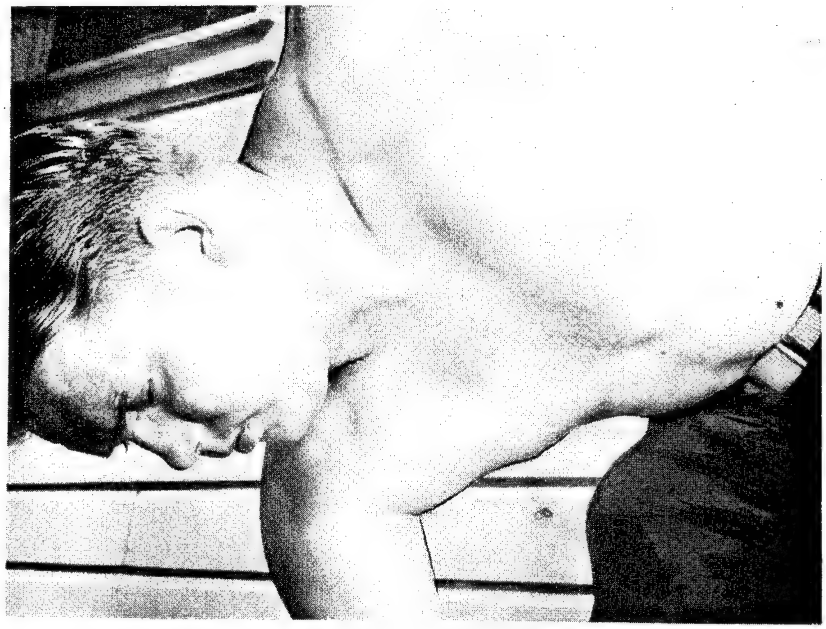
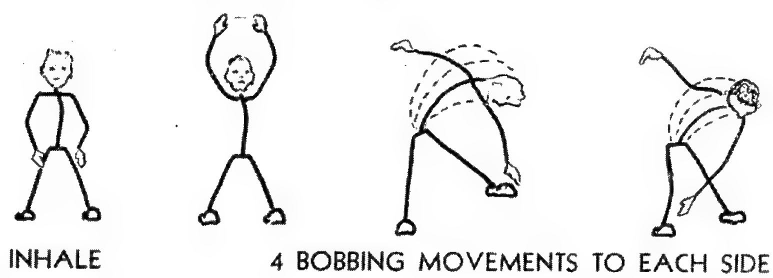


FIGURE 64.—Supplementary exercises. Shoulder swing (2).



Hold the breath . . . bend away down . . . bob vigorously.



MOVEMENT

1. Inhale deeply, raise arms forward to overhead position and draw in diaphragm.

2. Bend at the waist in a bobbing movement and alternately touch the left side of the left foot with fingers of the right hand four successive times.

3. Reverse and touch right side of right foot with the right hand four successive times. This movement is repeated until patient is forced to expel the air.

PURPOSE

1. Valsalva type exercise for mobilization of diaphragm and shoulder girdle muscles, through alternate compression and expansion of the hemithorax.

2. The bobbing action of the body causes a piston-like action of the diaphragm forcing air deep into the chest cavity.

FIGURE 65.—Supplementary exercises. Bobbing movements to each side (2).

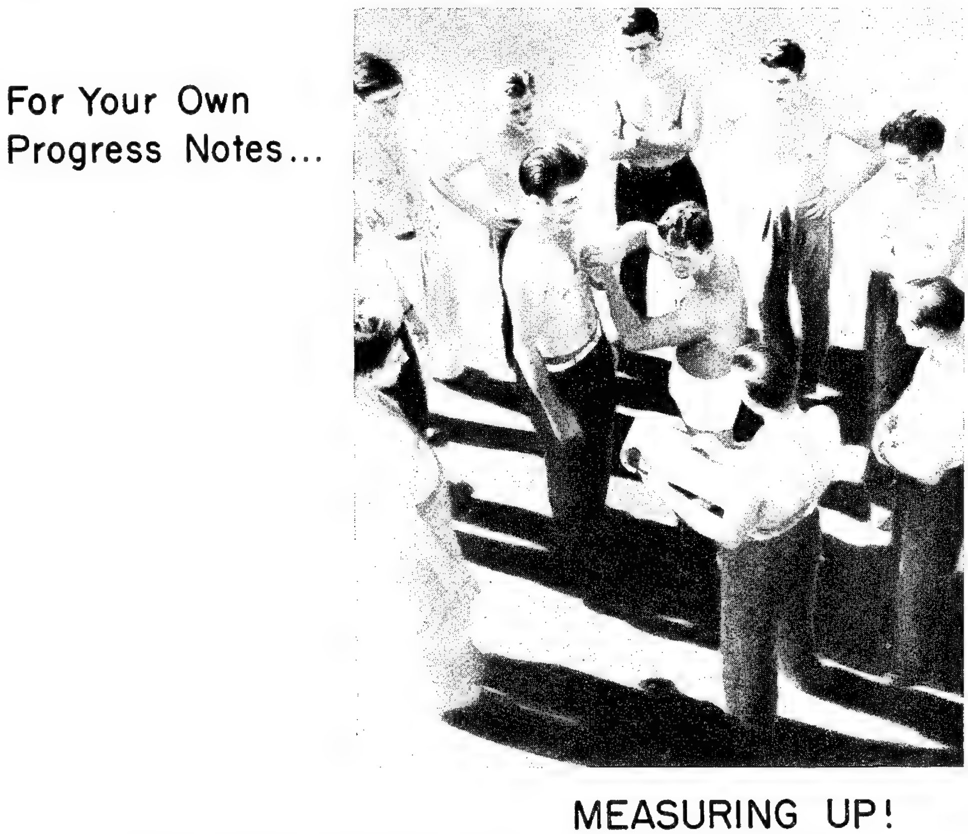
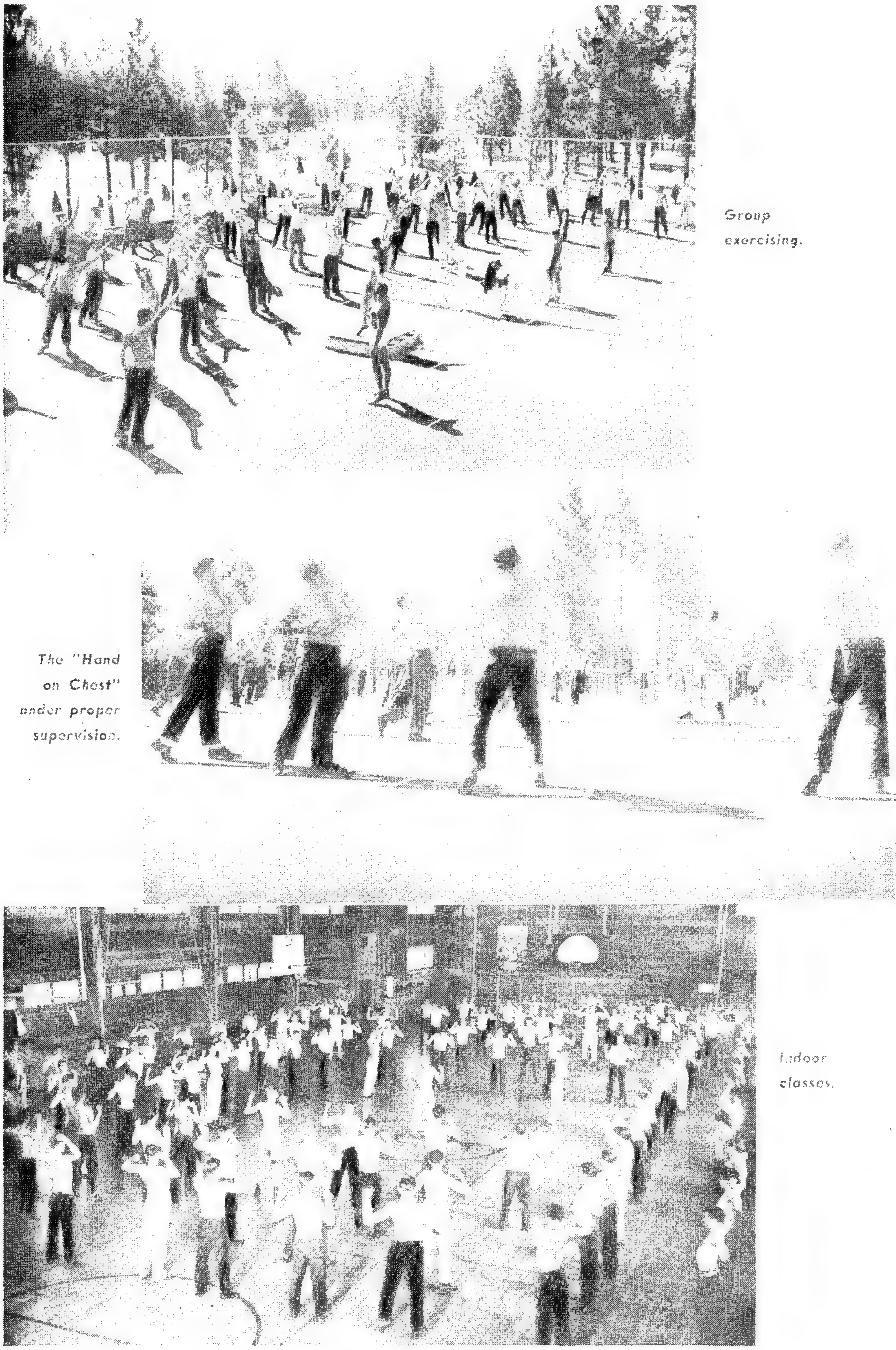


FIGURE 66.—Page used by patients to record their own progress (2).

7. After the 30th postoperative day, the reconditioning program lasted for an hour and a half twice a day. The first 45 minutes were devoted to the 12 thoracic exercises and the supplementary warmup exercises. The second 45 minutes were devoted to sports and games and were entirely recreational, though in the selection of activities those were stressed that would encourage continued stretching of the thoracic cage.

While the program outlined was the routine generally followed, the patient's progress from one phase to another depended entirely upon his individual performance, of which he kept his own records (fig. 66). All activities were conducted in small groups and were closely supervised by physical instructors (fig. 67).

About 45 days after operation, most patients were in suitable condition to be transferred to the Army Air Forces Reconditioning and Convalescent Regional Hospital, Fort George Wright, Wash. Here the remedial thoracic exercises were continued under supervision while the patients participated in the general physical reconditioning program directed by The Surgeon General.



Group exercising.

The "Hand on Chest" under proper supervision.

Indoor classes.

FIGURE 67.—Group exercises under supervision (2).

Results of Program

At the Baxter General Hospital chest center, it was noted that occasional patients who had made what seemed to be a complete surgical recovery from posttraumatic or postpneumonic empyema presented manifestations indicative of reactivation of the inflammatory disease when they began their reconditioning routine. The residual status of the disease had not been revealed by either physical or roentgenologic examination. The patients had arrived from other hospitals in apparently good condition, with their wounds well healed and no physical evidence of disability. When recurrent empyema manifested itself in this fashion, patients were referred to the surgical ward for operation, after proper preparation for it.

Another group of patients who had sustained some loss of substance of the thoracic wall as the result of either initial trauma or the extensive debridement required by it reacted to the exercise program by herniation of the lung through the defect. Those patients were also referred to the surgical section, for plastic reconstruction of the chest wall.

The exercise program thus unwittingly served as a valuable method of detecting physical fitness and of bringing to light promptly any residual defect or disability which might require further surgery.

It needed no more than simple clinical observation of the comparative progress of patients given breathing and other exercises with those not given them to prove that this program was one of the most valuable additions to the care of thoracic casualties. Patients not given these exercises complained of chest pain, dyspnea, and other disabilities, and also presented deformities of the chest wall. Early ambulation and the early use of these exercises generally eliminated this sequence. Patients consistently found that their exercise and activity tolerances increased as their respiratory function improved. It was exceptional, unless there were complications, that a patient submitted to thoracotomy for the removal of foreign bodies or for decortication was not able to participate in all but the most rigorous physical exertion within a month after operation. Gain in weight and strength and response to therapy for anemia, as well as the general well-being, always paralleled the increase in respiratory function.

The condition of thoracic casualties on discharge from the chest center was generally gratifying. Once it was explained to them, they readily realized the importance of their cooperation in these exercises in their own immediate rehabilitation and future health. As a result, these patients, like most other thoracic casualties of World War II, faced the world well and fit, and not as chest cripples.

References

1. Reed, J. M. W.: Post-Operative Breathing and Other Exercises. *In* Pye's Surgical Handicraft: A Manual of Surgical Manipulations, Minor Surgery, and Other Matters Connected with the Work of Surgical Dressers, House Surgeons, and Practitioners, edited by H. Bailey. Ed. 14. Bristol: John Wright & Sons, Ltd., 1944.

2. Thoracic Remedial Exercises as Developed and Presented at Baxter General Hospital, Spokane, Wash. Medical Research and Development, Thomas B. Wiper, Major, MC; Physical Reconditioning Research and Development, James T. Lang, Major, CAC; Leslie T. Wood, Captain, Inf.; David B. McClosky, Captain, AC; and Renold Cook, Technical Sergeant; 1945.

APPENDIX A

Thoracic Surgical Unit for 803d and 15th Hospital Centers 160th General Hospital

INSTRUCTIONS FOR THE PATIENT

In the past, people who have had injuries or diseases of the chest have been left deformed. You have had such an injury. You can look in the mirror and see this deformity. Your injured side does not move, when breathing, as well as your good side. In severe cases, the head and neck are shifted to the injured side—the shoulder on that side is lower—the chest is sunken, there is curvature of the spine, and the hips are tilted. This deformity of the head, neck, shoulder, chest, spine, and hips, labels a man as a "chest cripple" (fig. 1).

When the chest does not expand, the lung does not move; and when the lung does not move it becomes diseased.

There is no reason to have "chest cripples" because we now know how to prevent this tragedy with SPECIFIC REMEDIAL BREATHING EXERCISES and proper calisthenics. The use of breathing exercises for 10 minutes in every hour is a small price to pay for health.

SOLDIER, WE'VE TRIED TO CONVINCE YOU; YOU HAVE TO BE CONVINCED BEFORE YOU'LL TRY; AND YOU HAVE TO TRY IN ORDER TO GET RESULTS. FOLLOW INSTRUCTIONS AND *LOOK AT YOUR CHEST IN THE MIRROR AND YOU'LL BE CONVINCED.*

* * *

SOLDIER, IT'S YOUR CHEST, YOUR BODY, YOUR HEALTH, AND YOUR LIFE!!

* * *

Specific Remedial Breathing Exercises

There are three main types of breathing exercises, (a) lower chest (fig. 2); (b) upper chest (fig. 2); and (c) diaphragmatic (fig. 3). You should become so expert with these that you will be able to breathe with your injured side alone—*without moving your normal side.* You will even do better than this before long—you will be able to breathe with the upper or lower part of the injured side, as you like. This sounds like a circus act, and certainly you didn't know that a person could train himself to breathe with one or the other side of his chest—much less part of one side—but you can if you concentrate and persist.

Do each of the three types of exercises six times with a few seconds' rest between each group of six. If you do not rest a few seconds, you will get dizzy. Take in as much air as possible, and force out as much as you can each time. After 6 lower chest, 6 upper chest, and 6 diaphragmatic exercises, run through them again, and *again* and AGAIN for 10 minutes. DO THIS EVERY HOUR.

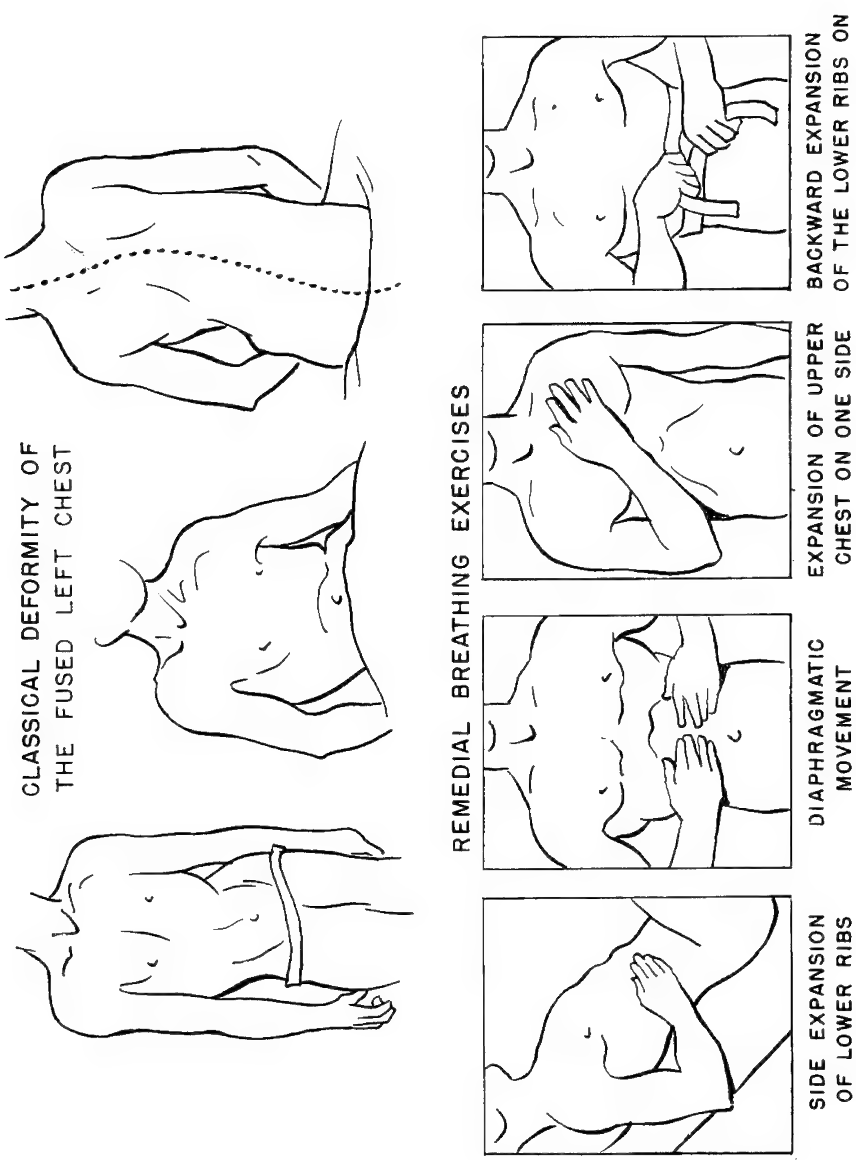
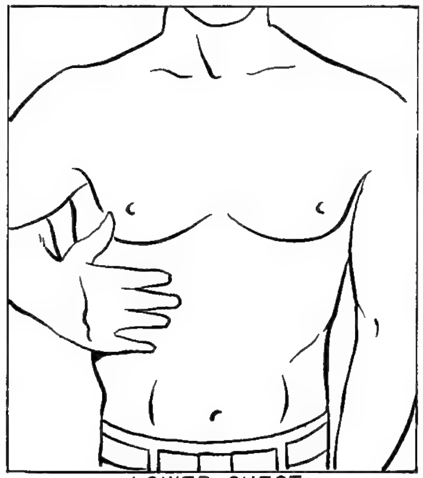


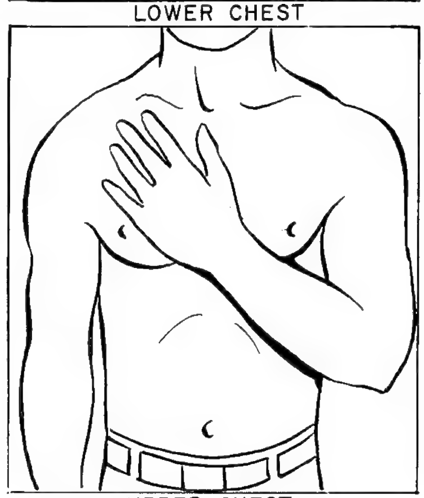
FIGURE 1.—Classical deformity of the fused left chest with remedial breathing exercises.

FIGURE 2.—*Lower chest.* Place your hand flat on the lower chest wall of your injured side. The finger tips should come just to the rib margin. Rest your hand lightly on the surface as you take in air slowly through your nose (inhale). Press firmly to help force air out through the mouth as you exhale. Take in as much air as possible then push out as much as you can. CONCENTRATE ON MOVING THE ONE SIDE. YOUR HAND HELPS LOCALIZE THE AREA THAT YOU ARE TRYING TO USE. WATCH YOUR HAND MOVE AND CONCENTRATE AS THE CHEST PUSHES IT OUT ON INSPIRATION AND AS YOUR HAND PUSHES THE CHEST IN ON EXPIRATION.



LOWER CHEST

FIGURE 2.—Continued. *Upper chest.* Same principle as lower chest exercise but the hand from the opposite side is used. The fingers fall just below the collar bone. It is more difficult to gain upper chest control, but as you can see in the mirror, this is an especially important area as it is generally badly sunken.



UPPER CHEST

CALISTHENICS

You will have a period of calisthenics every day, and these are very important too, but do not confuse your breathing exercises with calisthenics. Your calisthenics will straighten your spine, set your head straight on your shoulders, put your hips back in line and get you so that you can raise your arms above your head. Soon you will not look like a human question mark—or a feeble old man carrying a bucket of lead.

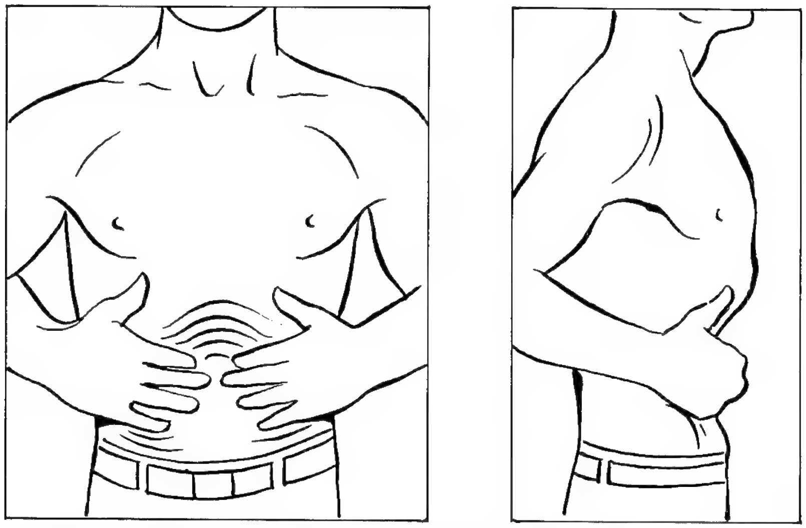
* * *

CONCENTRATE—PERSIST—CARRY YOURSELF STRAIGHT—WATCH YOUR PROGRESS IN THE MIRROR

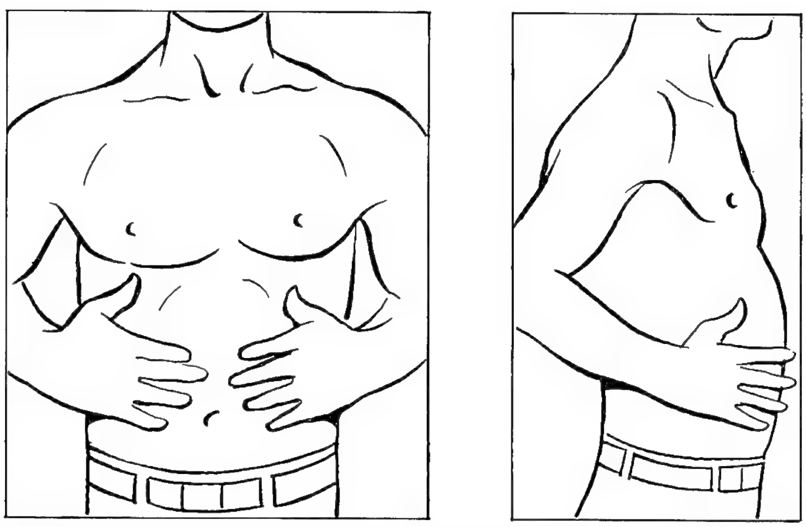
* * *

IT'S YOUR CHEST—YOUR BODY—YOUR HEALTH—YOUR LIFE—YOU OUGHT TO CARE

Dwight E. Harken
Major, MC
Consultant in Thoracic Surgery
803d and 15th Hospital Centers



BREATHING OUT (EXHALING) WITH THE DIAPHRAGM



BREATHING IN (INHALING) WITH THE DIAPHRAGM

FIGURE 3.—*Diaphragmatic.* The idea of diaphragmatic breathing is difficult to get over because you cannot see it work. The diaphragm is the partition between the organs in your abdomen and chest. This big sheetlike muscular partition is fastened to the lower rib margins, and when it moves up into the chest—like a piston—it forces air out of the lungs. *If you push in with your hands on your abdomen and blow out air through your mouth, you are making the diaphragm force air up and out of the lungs.* When you take in a very deep breath you must relax the pressure on your belly wall (and let it swell out)—this means that you are making the piston move downward and sucking in air through the nose. *Again, to make it clearer: push in on the belly and push air out through the mouth—then—breathe in through the nose and push the belly out.*

APPENDIX B

Army Service Forces

NINTH SERVICE COMMAND
BAXTER GENERAL HOSPITAL
SPOKANE, WASHINGTON

Subject: Thoracic Therapy Exercises
To: The Patients of Baxter General Hospital

Greetings to all patients who have been brought to us by the hazards of war for the curative measures that may be applied to you. We consider that the opportunity to help you is a high honor. While you are with us, your welfare in all respects will be our sacred trust. No skill or facility will be spared to assure that when our efforts in your behalf have been completed you will leave in the best condition, knowing that nothing has been omitted which could be done.

To obtain the optimal results, we want you to know that you will have a large part of the task of restoring yourself to normal health. To accomplish the maximum benefit in the shortest time, there are two simple rules: namely, to embrace all helpful measures fully and discard all retarding influences. As in so many of life's activities, we profit from opportunities in proportion to what we put into them. And so it is in recovery from wounds or disease, your intelligent cooperation will repay you manyfold. This booklet deals with reconditioning measures designed for your special type of disability. The processes set forth have been carefully worked out by experts in the field, are basically and scientifically sound, and have been proven in thousands of cases to accomplish their intended purpose.

At Baxter, we have highly skilled specialists selected from the medical profession of the entire country and assigned here for the purpose of caring for the types of injury and disease of which yours is one. Associated with them and assisting them in their work are a host of professional and technical specialists in related fields of action, all human, like you and me, intensely interested and enthusiastic and nothing makes them happier than successful progress and recovery of the patients whom they have so earnestly and conscientiously labored to cure. Their sense of satisfaction and happiness over successful recovery is scarcely exceeded by the patient's.

(Signed) A. B. McKie
Colonel, MC
Commanding

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[1] Unless otherwise specified, all entries in this index refer to injuries and diseases of the chest and their management in World War II.

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HISTORY OF THE MEDICAL DEPARTMENT, U.S. ARMY, IN WORLD WAR II

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